A Case Study of the Environmental and Economic Sustainability of Dairy Support Farms in the Selwyn - Te Waihora Catchment

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Charlotte Anna Irving

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Public and political concerns regarding the impact of agriculture on water quality have heightened in recent years in response to the declining water quality of New Zealand waterbodies. In response, Variation 1 of the Canterbury Land and Water Regional Plan requires nitrogen leaching from dairy support land in the Selwyn Waihora catchment to decrease by 22 percent beyond good management practices by 2022. Consequently, dairy farmers that own dairy support land within this catchment are under significant pressure to implement a system that meets the nitrogen constraints. This research uses a farm systems modelling approach to investigate the implications of nitrogen regulations on the performance of four dairy support farms in Selwyn Waihora. This research will help assist dairy support farmers in making informed decisions when considering how to mitigate their nitrogen leaching losses while not undermining the performance of their farming business. The outcome of this analysis is that nitrogen loss regulations are likely to reduce stock numbers on dairy support farms. Therefore, it is likely that owned dairy support land will be unable to meet the purposes it was purchased for; to attain direct control of livestock condition to enhance the performance of the overall dairy enterprise. Nitrogen regulations are also expected to reduce the operating profit of dairy support farms. This study reiterates the importance of farmer preference in selecting mitigations as some DSL farmers prioritise factors such as control over stock higher than profit levels. Overall, there is no 'one size fits all' approach to mitigating nitrogen leaching from dairy support farms, as these factors need to be considered on a farm specific and farm system basis.

Keywords: dairy support, wintering systems, nitrogen regulation, Variation 1, Selwyn Waihora, nitrogen mitigation, Farmax®, Overseer™

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Abbreviations

BCS: Body condition score

CP: Crude protein

CWMS: Canterbury Water Management Strategy

ECAN: Environment Canterbury

DCD: Dicyandiamide (a nitrification inhibitor)

DM: Dry matter

DSL: Dairy support land

EBIT: Earnings before interest and tax, including depreciation and expenses

GMP: Good management practice

Ha: Hectares

LWRP: Canterbury Land and Water Regional Plan

MP: Milking platform

N: Nitrate/nitrogen

NPSFM: National Policy Statement for Freshwater

PAW: Profile available water

Selwyn Waihora: The Selwyn-Te Waihora/Lake Ellesmere catchment

Variation 1: The Selwyn Waihora sub-region in the Canterbury Land and Water Regional Plan

Key Terms

Milking platform (MP): An area of land used for grazing lactating cows during the milking season

Dairy support land (DSL): An area of land that provides support to the milking platform by wintering cows, growing supplementary feed and raising young stock. Dairy farmers commonly refer to their owned DSL as a “runoff”.

Chapter 1

Introduction

1.1 Overview

The New Zealand dairy industry has expanded and intensified significantly in the last two decades, generating an increased need for dairy support land (DSL). An increasing number of dairy farmers, particularly those in the South Island, choose to use all of their dairy farm as a milking platform (MP) and therefore rely on DSL to enhance the overall success of their whole dairy operation (SIDDC, 2008). In addition to wintering cows, DSL supports the MP by rearing replacement stock, producing supplementary feed, and carrying over empty cows.

Most dairy farmers prefer to own DSL rather than rely on third party grazier support services, primarily to maintain control of cow condition over winter (Richards, 2006), which directly influences the production potential of the herd in the subsequent milking season (Roche et al., 2009). However, there has been considerable debate in regard to the benefits of owning DSL and whether owned DSL is financially viable relative to other alternative grazing options such as third party graziers or leased DSL (Woodford, 2006; Richards, 2006). Further, recent nitrogen constraints imposed by some regional councils are likely to impede the financial viability and productivity of owned DSL. In particular, Variation 1 of the Canterbury Land and Water Regional Plan (LWRP) requires dairy support farmers in Selwyn Waihora to reduce the nitrogen losses on their farm 22% beyond good management practice (GMP) by 2022 (ECAN, 2015). Consequently, dairy farmers that own DSL within Selwyn Waihora are under significant pressure to implement a system that meets the nitrogen constraints while not undermining the performance of their farming business.

This research uses a case study approach to explore the environmental and economic sustainability of DSL in the context of the Selwyn Waihora catchment. This research focuses on exploring the implications of Variation 1 on the physical, environmental and financial performance of individual dairy support farms. Overall, the research aims to identify how farmers in the catchment can achieve the nitrogen limits in the most cost-effective manner.

1.2 Research objective and relevance for the dairy industry

The main objective of this research is to examine the implications of nitrogen reduction limits on different types of DSL in the Selwyn Waihora catchment. The physical and financial performance levels achieved by New Zealand dairy farms are widely known (DairyNZ & LIC, 2015). Further, in light of the National Policy Statement for Freshwater Management (NPSFM), many studies have focused on the nitrogen losses from pastoral dairy farming, and the current mitigations available for mitigating on-farm nitrogen losses and their respective cost-effectiveness (for example Kaye-Blake et al., 2014; Smeaton, Cox, Kerr & Dynes, 2011; Vibart et al., 2015; Vogeler et al., 2014). Regional councils and industry good bodies, such as DairyNZ[1], have quantified the financial implications of regional environmental policies on dairy farms (DairyNZ Economics Group, 2015).

However, few in-depth investigations have explored DSL in Canterbury, particularly in regard to the financial feasibility, physical performance levels, and nitrogen leaching rates achieved through different DSL management operations. In the past focus has been placed on using a case study approach to gain insight into the management operations and profitability levels inherent in dairy support ownership in Canterbury (Richards, 2006). Bennett (2009) also broadly explored factors influencing the sustainability of DSL in Canterbury. These case studies however, were undertaken prior to the implementation of the initial NPSFM in 2011 (revised in 2014) and therefore lack consideration of the implications of farmers having to meet nitrogen loss targets on their DSL.

Research to date has largely excluded consideration of the implications of nitrogen policies on dairy support farmers. This exclusion is due to the absence of robust, accessible data from applied research and industry good bodies (such as DairyNZ), partly due to lack of distinction between DSL and other farm enterprises in terms of land use, with many properties being inherently interchangeable. In addition, most of the industry focus is on the MP, as that is where most of the profit and performance is measured. Variation 1 has heightened the need for sustainable management of DSL in the Selwyn Waihora catchment, and could result in many physical, financial and environmental changes. Further, farmers

[1] DairyNZ is the industry good organisation for New Zealand dairy farmers, which, among other things, develops applied research and collects data in response to current industry needs.

need to be able to understand how to meet their nitrogen constraints in the most cost-effective manner, to ensure their DSL meets the purposes it was purchased for.

The results from this research will assist DSL farmers in making informed decisions when considering how to mitigate their on-farm nitrogen losses. This will be valuable to the New Zealand dairy industry, as farmers are challenged to farm within environmental limits while not undermining their economic performance. This research will also contribute to the literature by complementing the few studies that consider the impact of environmental regulations on the cash operating profit of DSL, which will be of benefit to the regional councils that are yet to implement on-farm nitrogen discharge limits under the NPSFM. Finally, this research will also highlight areas where future research would be beneficial to support the sustainability of DSL.

1.3 Research questions

1. What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?
2. What are the current management practices used on DSL in Selwyn Waihora?
3. How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?
4. How will Variation 1 impact the future physical, environmental and economic performance of owned DSL?
5. How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

1.4 Research approach

A case study approach was chosen for this research, to explore the implications of Variation 1 in context of the conditions and constraints unique to each farming system. Four dairy farmers that own DSL in the Selwyn Waihora catchment in Canterbury were interviewed to provide data for subsequent analysis. Data was sought on the physical, financial and environmental levels currently achieved by DSL, as well as qualitative information pertaining to DSL ownership and the farmers preferred nitrogen mitigation strategy. Farm systems modelling was then undertaken to analyse the implications of reducing nitrogen losses on the four DSL farms. Overseer™ (6.2.3) was used to model the impact of mitigation strategies on nitrogen loss, while FARMAX® Pro (7.1.0.31) was used to ensure that viable farm scenarios were being represented and model the financial implications of mitigation options. These two modelling tools were used simultaneously to create an abatement curve for each case study farm - to understand the impact of reducing nitrogen loss on cash operating profit. Chapter 4 contains detailed information regarding the methodology used.

Chapter 2

Background

2.1 The Selwyn Waihora Case Study

The Selwyn Waihora catchment is located in central Canterbury in the South Island, New Zealand. The geographic area covered by the Selwyn Waihora sub-region in the Canterbury Land and Water Regional Plan (LWRP)[2] is hydrologically bounded by the Waimakariri and Rakaia Rivers, and encompasses the catchment that flows east into Te Waihora (figure 1). This includes the foothill sub-catchment of the Waikirikiri/Selwyn River and its tributaries, the plains between the Rakaia and Waimakariri Rivers, part of the Halswell River/Huritini catchment, lowland spring-fed streams, and several ephemeral Banks Peninsula streams that flow into Te Waihora (ECAN, 2015). Te Waihora, also known as Lake Ellesmere, is a highly modified brackish lake which discharges into the South Pacific Ocean. It is New Zealand's fifth largest lake, with an approximate area of 20,000 hectares, and an average depth of 1.4 metres (Hughey & Taylor, 2009).

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Figure 1: Map of the Selwyn Waihora sub-region zone. (ECAN, 2015, p. 196).

[2] The Selwyn Te Waihora sub-region in the LWRP does not apply to the entire Selwyn Waihora Water Management Zone in the Canterbury Water Management Strategy, as it excludes the alpine boundary in the north-west (the headwaters of the Waimakariri River and part of the headwaters of the Rakaia River, including Lake Coleridge).

The catchment area covered by Variation 1 encompasses a total area of 272,000 hectares and includes a vast array of geographical features (ECAN, 2014). It is hydrologically diverse, characterised by alpine and hill-fed rivers, groundwater zones, spring-fed lowland streams, an extensive drainage system, and Te Waihora (Canterbury Water, 2011). Figure 2 illustrates the hydrological system of the Selwyn Waihora catchment, highlighting the interconnection of surface and groundwater. The groundwater resource is derived from land surface recharge and river seepage (Hanson & Abraham, 2009; Robinson & Davies, 2013), which is largely influenced by the high permeability of the soils and riverbeds in the upper plains (Burden, 1984). River seepage infiltrates downward into the deep parts of the aquifer system, discharging to the South Pacific Ocean via offshore groundwater flow. Land surface recharge (i.e. soil water drainage across the plains) remains in the shallower parts of the unconfined aquifer system (Hanson & Abraham, 2009), resurfacing in lowland spring-fed streams which discharge to Te Waihora (Clark, 2014; Hanson, 2014; Scott & Weir, 2014). Considerable time can lapse between when water infiltrates through the soil on the plains and when it resurfaces in a lowland stream (i.e. time lag effect) (Bidwell et al., 2009).

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Figure 2: A conceptual hydrological model of the Selwyn Waihora catchment (Williams, 2014, p. 2).

The rainfall and climate of the Selwyn Waihora catchment varies from the foothills in the west to the coastal boundary in the east (Swanson, 2014). The Canterbury Plains are characterised with low unpredictable rainfall, a large temperature range, and high evapotranspiration rates and soil moisture deficits (figure 3) (Macara, 2016). The rainfall average increases in the western catchment with the high country near the main divide receiving abundant rainfall and winter snow (Macara, 2016; Ryan, 1987). The Canterbury Plains were formed from postglacial fluvial sediment deposits originating from the Southern Alps and fine-grained marine deposits (Thorpe, 1992). As a result, the soils in the Selwyn Waihora catchment also have a wide range of soil drainage behaviours and water holding capacities (Landcare Research, 2016). Stony, shallow soils dominate the plains, while heavier soils surround the coastal extent of the catchment.

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Figure 3: Median annual total rainfall (left) and median annual days of wilting point deficit (right) for Canterbury, 1981-2010. (Macara, 2016, pp. 16, 35).

The catchment is encompassed within a single regional authority – Environment Canterbury (ECAN) and two territorial authorities – Selwyn District Council[3] and Christchurch City

[3] The Selwyn District covers an area wider than the Selwyn Waihora catchment (650,000 ha and 272,000 ha respectively), however the catchment is prominently on the plains and therefore consists of a large proportion of the District's population.

Council. The Selwyn District was New Zealand's fastest growing territorial authority from 2006 to 2013, increasing by a third (10,953 people) to 44,595 (Statistics NZ, 2013a), largely due to the devastating series of Christchurch earthquakes and rapid growth in townships such as Lincoln, Rolleston and Prebbleton. Recent projections estimate the population will almost double, to 86,440, by 2041 (SDC, 2015). Employment and economic statistics for the Selwyn District highlight its considerable reliance of the agriculture industry (Harris Consulting, 2014). For instance, the agriculture, forestry and fishing sectors accounted for 18.7% of employment in the district in 2013, as compared to only 5.7% for New Zealand (Statistics New Zealand, 2013b). Guenther, Greer, Saunders and Rutherford (2015) found that the average farm in the Selwyn and Waimakariri Districts spent $73,137 on goods and services in Christchurch in 2010-11, totalling $645 million in direct, indirect and induced expenditure into the Christchurch economy.

Table 1 shows the proportion of each land use group in the Selwyn Waihora catchment in 2011, highlighting the diversity of land use within the catchment. Sheep and beef farming was the dominant primary land use, followed by dairy and arable. Over the last two decades, land use has changed significantly, reflected by the conversion of traditional sheep and beef farms to intensive dairy operations (refer to section 2.2).

Table 1: Summary of the area of each land use (derived from the dominant land use on each farm) in the Selwyn Waihora catchment in 2012. Data dervived from Lilburne (2014).

Land use	**Area (ha)**	**Percentage of the catchment**
Sheep and beef	93,116	34.2%
Dairy	45,819	16.8%
Arable	29,959	11.0%
Dairy support	21,853	8.0%
Plantation forestry	10,695	3.9%
Native vegetation, conservation, and lakes and rivers	2,541	0.9%
'Other' agriculture	8,905	3.3%
'Other' non-agriculture	17,012	6.2%
Unknown	42,340	15.6%
Total	**272,240**	**100%**

Other agriculture = Deer, pigs, orchards, vegetables
Other non-agriculture = Residential and lifestyle
Unknown = Land with unidentified ownership

Typical to the wider Canterbury region, irrigation is a significant feature of the Selwyn Waihora catchment. Irrigation abstraction has increased steadily over the last few decades (ECAN, 2012), enhancing agriculture productivity and economic growth (Harris Consulting, 2014). Approximately 105,000 hectares (or 49%) of the catchment's agriculture land is currently irrigated, sourced primarily from groundwater (ECAN, 2014). In addition, Central Plains Water Limited (CPW) has consent for irrigation development in the upper catchment. The scheme will use alpine surface water to irrigate 30,000 hectares of dryland (new irrigation) and replace groundwater takes on 30,000 hectares of existing irrigated land in the command area. Full development of the CPW irrigation scheme is expected to be complete by September 2018 (CPW, 2013). The Zone Committee Solutions package[4] assumes that new irrigation provided by CPW will convert dryland land uses to dairy (40%), arable (40%), sheep and beef (13%) and dairy support (7%) (Canterbury Water, 2013). However, fluctuating global milk prices have made this economic development appear risky, suggesting that the level of CPW uptake from dairy farmers may be revised downwards (Eppel, 2015).

2.2 Dairy farming in the Selwyn Waihora catchment

The Selwyn Waihora catchment, like the wider Canterbury region, has experienced an expansion in dairying in recent years (ECAN, 2014). This is supported by lower land prices relative to other regions, irrigation development, the adoption of new technologies, and the reduced returns from traditional pastoral farming systems (Dynes, Burggraaf, Goulter, & Dalley, 2010; Pangborn & Woodford, 2011). Since the 1990s, dairying land use and dairy cow numbers have experienced the largest overall change and increase in the Selwyn District, relative to other agriculture land uses and livestock numbers (Mactier, 2011).

Figure 4 shows the change in total cows, hectares and milksolids between 1996-97 season and 2014-15 season, according to the NZ Dairy Statistics (DairyNZ & LIC, 2015). This indicates a linear annual growth rate of 7% for total cows in Selwyn, 6% for total effective hectares and 9% for total milksolids. Figure 5 shows the change in milksolids per effective

[4] Following extensive consultation and collaboration with stakeholders, the Selwyn Waihora Zone Committee prepared the Selwyn Waihora ZIP Addendum in 2013, which recommends a water management solutions package.

hectare, milksolids per cow and cows per effective hectare between 1996-97 and 2014-15, highlighting the gradual increase in milk production. Growth rates are relatively uncertain in the future, given the effect of the volatile milk price and the future increase in irrigated dairy land provided by the CPWL scheme. In particular, the lowered milk price reduced the number of dairy cattle in New Zealand by 3% in 2015, which was the first decrease since 2005, as farmers have culled their lower producing cows to maximise their milk production and production efficiency (Statistics NZ, 2016).

In 2014-15 the Selwyn District had 218 dairy herds with a total of 160,955 cows and 49,063 effective dairy hectares (DairyNZ & LIC, 2015) (figure 4). This equates to the average herd milking 738 cows on 225 effective hectares (3.28 cows per hectare). Selwyn has 17.6% of Canterbury's total dairy cows, 19.2% of the dairy herds, and 18.6% of the regional dairy land. In terms of production, the Selwyn District produced over 66 million kilograms of milksolids, or an average of 411 kilograms of milksolids per cow and 1,348 per effective hectare (DairyNZ & LIC, 2015) (figure 5).

Dairy farming is a significant contributor to the regional economy, employing 1,206 on-farm workers in 2014 (Harris Consulting, 2014), including 168 owner operators and 50 sharemilkers in 2015-16 (DairyNZ & LIC, 2015). In addition to the on-farm workers, approximately 500 people are employed in three major dairy processing plants, Fonterra at Darfield, Synlait at Dunsandel and Westland Milk at Rolleston (Ryan, 2014). According to Harris Consulting (2014), dairy farming (excluding manufacturing) contributed nearly 64% ($510 million) to the Selwyn Waihora catchment agriculture sector total gross domestic product from 2010 to 2013, despite only occupying 19% of the total catchment land use.

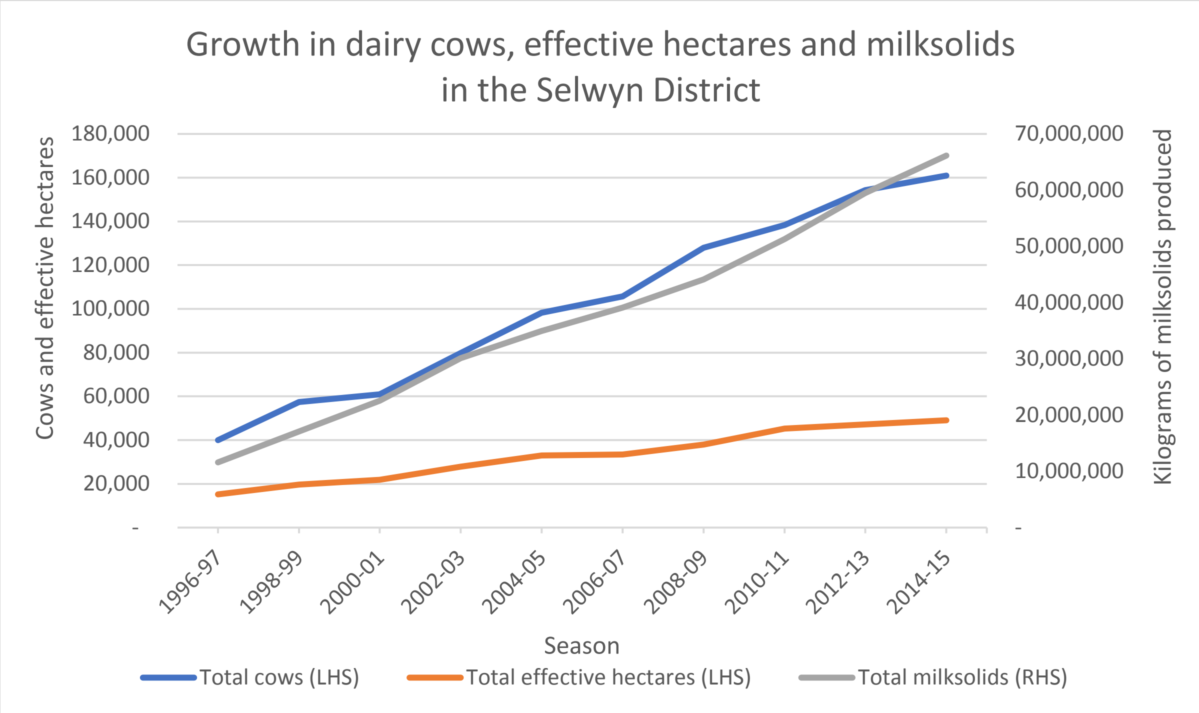

Figure 4: Growth in dairy cows, effective hectares and milksolids in the Selwyn District, 1996-97 to 2014-15. (DairyNZ & LIC, 2015).

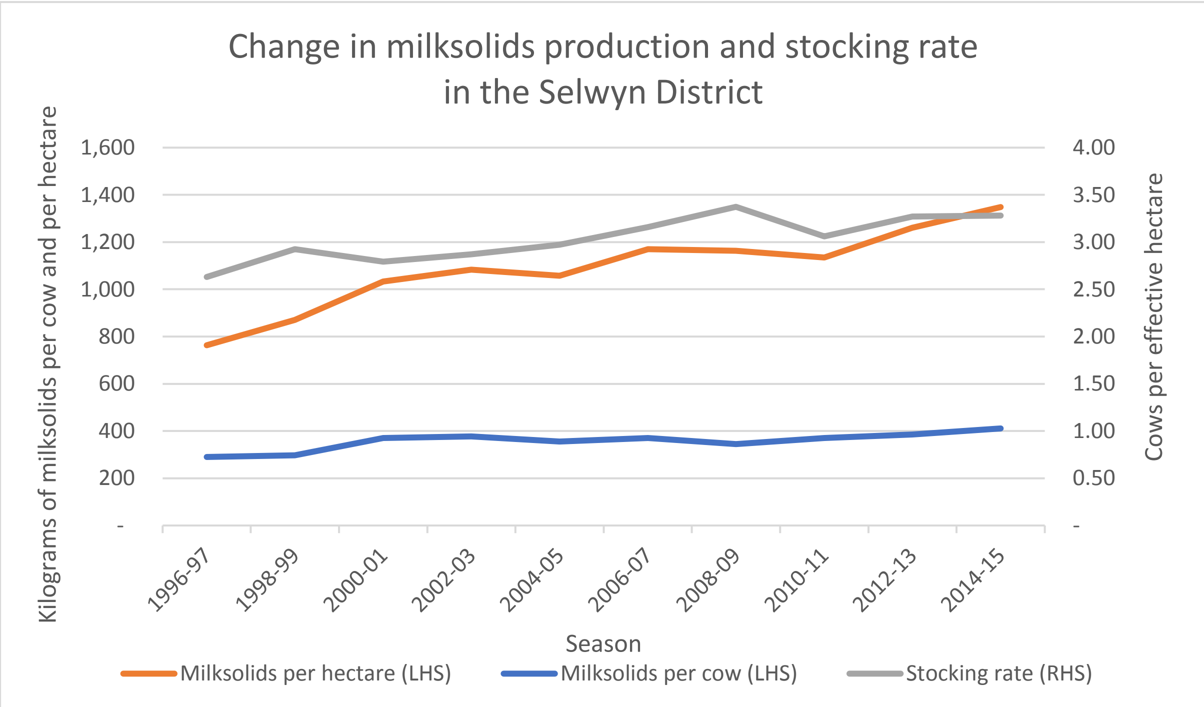

Figure 5: Change in milksolids production and stocking rate in the Selwyn District, 1996-97 to 2014-15. (DairyNZ & LIC, 2015).

2.2.1 Dairy support farms in the Selwyn Waihora catchment

The expansion and intensification of dairy farming in Selwyn Waihora has increased the requirement for DSL; to support the MP by wintering cows, grazing replacements and growing supplements (SIDDC, 2008; Dynes et al., 2010; Peel, 2013).

Despite its significance as an integral component of the overall dairy operation, there is little consensus surrounding the location and total area of DSL in the Selwyn District. In terms of land use, this is largely due to the lack of distinction between dairy support and other farm enterprises, with many properties being inherently interchangeable, as well as the lack of robust AgriBase GIS information (Ford, 2014). Lilburne (2014) and Harris Consulting (2014) estimated that there was 21,853 and 24,974 hectares of DSL in the Selwyn Waihora zone in 2014 respectively. Harris Consulting (2014) assumes about half this land is irrigated and the ratio of DSL to dairy is 0.55. Lilburne (2014) expects there are 243 dairy support farms, of which 82% (18,000 hectares) is integrated into sheep and beef farms.

2.3 Water quality in the Selwyn Waihora catchment

Under the NPSFM ECAN is required to set water limits that will maintain and improve freshwater values (MFE, 2014). This research focuses on the implications of the water quality limits set by ECAN in the Selwyn Waihora sub-regional section of the LWRP, particularly the physical and financial impacts of reducing nitrogen leaching per hectare on dairy support farms. While it does not attempt to take a position on freshwater quality in the Selwyn Waihora catchment, it is imperative farmers recognise the current state of freshwater bodies in their catchment, as this forms the basis of the limits in Variation 1.

Water quality in New Zealand catchments has generally declined due to agriculture intensification (Hamill & McBride, 2003; Ballantine & Davies-Colley, 2009; Monaghan et al., 2007), and Selwyn Waihora is no exception (Golder Associates, 2011; Hanson, 2014). Most of the lowland stream monitoring sites in the catchment do not meet water quality objectives set in the LWRP for biodiversity protection (Hanson, 2014). Two downstream sites of the Selwyn River (Coes Ford and Upper Huts) had faecal contamination at levels unsuitable for recreational use in the 2015-16 summer (ECAN, 2016), however it was not specified which land use this was from.

In terms of nitrate concentrations, it is important to recognise the strong relationship between water quality, catchment land use, soil drainage types, groundwater abstraction and tributary flows. For instance, the impact of intensive agriculture is exacerbated by the light stony soils that dominate the catchment and pose a significantly high risk for nitrogen leaching to groundwater, particularly in the upper to mid-catchment (Webb et al., 2010) (refer to figure 6). Further, increasing groundwater abstraction and long-term climatic variation has contributed to low and declining flows in tributaries, which indirectly contributes to reduced water quality in lowland streams (Williams, 2008; Hanson, 2014).

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Figure 6: Nitrate leaching vulnerability for the Central Canterbury Plains according to soil plant available water and denitrifcation attenuation (Webb et al., 2010, p. 8)

The most significant environmental concern in the Selwyn Waihora catchment is the continuous degradation of the ecological and cultural values provided by Te Waihora. The shallow brackish lake is classified as a wetland of international significance, and is highly prized by Ngai Tahu (ECAN, 2015). However, Te Waihora "naturally functions as a sink for its catchment area" (Hearnshaw & Hughey, 2010, p. 1), which has become increasingly dominated by intensive agriculture and urban land use. Consequently, Te Waihora has been rated as having the poorest nutrient status of 140 New Zealand lakes according to a study by the National Institute of Water and Atmosphere (Verburg, Hamill, Unwin, & Abell, 2010). Despite its highly enriched state, Te Waihora supports a highly valued, abundant ecosystem, and does not exhibit the characteristics that are typical of severely degraded lakes (such as severe oxygen depletion and regular toxic cyanobacteria blooms) (Hughey et al., 2009). Poor water quality, however, fails Ngai Tahu values and expectations (Tipa, 2014).

The Selwyn Waihora catchment is over-allocated with respect to water quality, as it is currently not achieving all its freshwater objectives. Further, it can take considerable time for land use nitrogen loads to resurface in lowland spring-fed streams via groundwater, and deposit into Te Waihora. With no further land use intensification in the catchment, the current load of total nitrogen entering Te Waihora in the next 10 to 20 years has been estimated to increase by 35%, as a result of the cumulative effects of past and current land use (Norton et al., 2014). Therefore, the Selwyn Waihora catchment is substantially over allocated in accordance with NPSFM, as water quality will get worse before it can get better. Under the NPSFM, ECAN are obligated to maintain or improve freshwater resources. The regulatory framework to achieve this, in particular Variation 1, is explained in the following section.

2.4 Selwyn Waihora catchment nutrient management: Variation 1

In the last decade, water governance, planning and management have shifted significantly to address the popular concern and critical issues surrounding freshwater management in Canterbury and New Zealand (Duncan, 2014a). Under the Resource Management Act (RMA) (1991), the central government passed the NPSFM in 2011, which was later revised in 2014 (MFE, 2014). The NPSFM provides the overarching framework for freshwater management in New Zealand, and places regulatory obligations on regional councils to manage their region's water resources in an "integrated and sustainable way, while providing for economic growth within set water quantity and quality limits" (MFE, 2014, p.3).

The Canterbury Water Management Strategy (CWMS) which was launched in 2009, prior to the NPSFM, also sought to set water quality limits. This was the response following recognition that a shift was needed from 'effects-based' management of individual consents (adopted under the RMA) to integrated, collaborative management based on the management of cumulative effects of land-use intensification and water abstraction within water management zones (Jenkins, 2011). The CWMS established ten water governance bodies known as Zone Committees across the region. The Zone Committees are charged with developing a Zone Implementation Programme (ZIP) that addresses their freshwater issues, through collaborative community engagement and consensus decision making. The Selwyn Waihora Zone Committee was established in 2010 and completed its ZIP Addendum in 2013. The overall vision of this non-statutory document was to improve cultural and environmental outcomes in the catchment, particularly Te Waihora, while maintaining farm viability and economic growth (Canterbury Water, 2013). ECAN endorsed the ZIP Addendum, which formed the basis for the Selwyn Waihora sub-regional section of the LWRP (operative February 2016). This was the first sub-region change made to the LWRP and therefore is commonly referred to as Variation 1. Within the LWRP, Section 4 and 5 as well as Schedule 8 outline the overall regional rules for nutrient management. This research focuses on the specific rules of Variation 1.

Variation 1 establishes limits, targets, timeframes and additional policies in the Selwyn Waihora catchment to address water quality and over allocation (ECAN, 2015). A key aspect of Variation 1 is the implementation of a catchment total nitrogen load limit for farming activities, to achieve the desired outcomes for groundwater and surface water quality, particularly in lowland streams and Te Waihora. The catchment load limit for farming activities (including those newly irrigated farms under CPW) is 4,830 tonnes of nitrogen per annum, to be met by 2037. This limit was derived by a revised 'Look-up' Table (Lilburne, Webb, Robson, & Watkins, 2009) which provides theoretical estimates of nitrogen loss rates (assuming GMP) for each relevant land use depending on the particular farm properties soils types and climate.

In order to achieve the target catchment load, farmers are required to reduce their nitrogen losses. With respect to dairy support farmers, the regulations in Variation 1 state that up until 2017 farmers must not exceed their nitrogen baseline (if their baseline exceeds 15 kgN/ha/year). The baseline is the four-year (2009 to 2013) average of their properties nitrogen loss, calculated using Overseer (ECAN, 2015). For nitrogen losses over 15 kgN/ha/year, in addition to remaining under their nitrogen baseline, farmers will need to implement GMP's (defined in Schedule 24 of the LWRP) by 2017.

In 2022 a further 14% reduction in average nitrogen losses across the catchment is required. In terms of dairy support farmers, the plan requires nitrogen loss reductions of 22% beyond

GMP by 2022 (table 2). This policy excludes DSL with nitrogen losses that are under 15 kgN/ha/year and dryland farming activities that will be irrigated by CPW (see section 2.4.2). The specific reduction limits also differ for farms that form a farming enterprise (see section 2.4.1). Resource consents will be required for those farmers who are unable to immediately achieve these limits, in addition, nitrogen losses greater than 80 kgN/ha/year will be strictly prohibited from 2037. Overall, it is evident that the plan will present many challenges for dairy support farmers in coming years.

Table 2: Nitrogen loss (kgN/ha/year) reductions required from farming properties in the Selwyn Waihora catchment by 2022, under Variation 1 of LWRP (Policy 11.4.16). (ECAN, 2015).

Farming activity	**Nitrogen loss (kgN/ha/year) reductions required from farming properties by 2022** (if the properties nitrogen losses exceed 15kgN/ha/year)
Dairy	30%
Dairy support	22%
Pigs	20%
Irrigated sheep, beef or deer	5%
Dryland sheep and beef	2%
Arable	7%
Fruit, viticulture or vegetables	5%

The setting of phosphorus limits has not yet occurred within the catchment, however under Variation 1, the key method for reducing on-farm phosphorus loss is through farm environmental plans (including fertiliser/soil and riparian management) and the exclusion of stock from waterways. As a matter of practicality, Variation 1 differentiates the management of nitrogen and phosphorus, largely due to their different chemical nature. For instance, unlike nitrate, phosphate compounds are relatively insoluble and bind strongly to particles (sediment or organic material), therefore activities which disturb soil contribute to the majority of phosphate losses through surface runoff, as well as the direct deposition of urine/faecal matter or fertiliser into waterbodies (DairyNZ, 2013a; McDowell, Biggs, Sharpley, & Nguyen, 2004; Sharpley, Gburek, Folmar, & Pionke, 1999). The techniques for nitrogen leaching estimation are more developed and robust, and on-farm phosphorus limits have not been established, therefore this research only evaluates the impacts of reductions in nitrogen leaching.

2.4.1 Farming enterprises

Under Variation 1, farming enterprises can be established in which all non-connected parcels of land owned by one entity are grouped into a single land entity for the purposes of nutrient management. Reductions in nitrogen losses will also be required by 2022 according to the weighted average of the nitrogen reductions required from the particular farm activities used in the enterprises. For instance, an enterprise with 50 hectares of dairy land and 50 hectares of DSL will be required to reduce losses by 26%, as this is the average reduction required (dairy and dairy support activities must reduce losses by 30% and 22% respectively under Variation 1).

2.4.2 Irrigation scheme: Central Plains Water Limited

Nitrogen losses from dryland farms converting to irrigation supplied by CPW after the 1st January 2015 are to be accounted for by the CPW scheme, whereby the scheme is responsible for the administration of nitrogen discharge consents from the shareholders, as well as management of FEP implementation, audits and annual reporting to ECAN. Under Variation 1, CPW has been allocated 979 tonnes of nitrogen to distribute among their shareholders at their discretion based on an assessment of the difference between the dryland nitrogen baseline for their farming system and the nitrogen loss model for the proposed farming system within the limits of GMP. CPW is also required to limit initial nitrogen losses from these properties to GMP via farm management plans.

Chapter 3

Literature Review

3.1 Introduction

The purpose of this literature review is to evaluate the research that has been conducted on DSL systems in Canterbury, particularly in regard to the nitrogen leaching on DSL and the costs of mitigation. This review will highlight research gaps and where this research project can contribute to the current body of literature.

In addition to peer reviewed literature this review analyses a range of articles that can be classed as 'popular' literature, appearing in farmer conference proceedings and government documents; non-peer reviewed text which is often opinionated and subjective. However, the exploratory nature of this research means that popular literature is both important and necessary in providing information on current dairy support systems within the Selwyn Waihora catchment.

3.2 Dairy support farm systems in Canterbury

The majority of dairy farmers in Canterbury operate with a MP structure, essentially using their dairy farm as an intensive MP to achieve high stocking rates and high productivity over the milking season (Hockings, 2002; Peel, 2013). In the South Island, this strategy has been found to be more profitable than wintering cows on the MP, which results in lower pasture covers during the milking season and therefore a smaller herd (Cottier, 2000; Davis, 2005; Hockings, 2002; de Wolde, 2006). Further, some Canterbury farmers face a period over winter where heavy soils become waterlogged increasing the potential for pugging (i.e. damage to soil physical properties), resulting in declines in subsequent pasture production (Singleton & Addison, 1999). Therefore, in order to protect the production potential of their MP, many Canterbury dairy farmers are reliant on DSL; land that provides support to the MP by wintering cows, growing supplementary feed and raising young stock. Further, as dairy farmers strive to increase their productivity, the reliance and demand for dairy support services is likely to become greater. However, anecdotal evidence suggests the latest milk price downturn has resulted in a reduction in heifer replacement rates, an increase in farmers growing winter feed on the MP, and a decrease in supplementary feed use (Journeaux & Savage, 2016). This suggests that in low payout conditions, farmers are willing to sacrifice milk production in order to reduce operating expenditure.

Dairy support land can be utilised by the dairy farmer for a number of different purposes. Research on owned dairy support blocks in Canterbury found that although wintering non-lactating cows and supplying supplements to the MP were generally the most important management practices, many diverse complementary enterprises existed which contributed to the profitability of the system (Richards, 2006; Peel, 2013). These enterprises included heifer grazing, dairy beef rearing and fattening, and cash cropping. Likewise, Bennett (2009) and Dalley, Wilson, Edwards and Judson (2008) observed that operations on DSL are very diverse, however their primary use was wintering cows on forage crops. Overall, the relative scale of the DSL to the MP (Richards, 2006), the degree of feed deficiency on the MP (Dalley et al., 2008), and the capabilities of management and the land being farmed (Bennett, 2009), were the key determinants of the range and extent of enterprises that the land supported.

There are various forms of DSL systems, including owned or leased support blocks separate to the defined MP (either as adjacent or separate blocks) or land farmed by a third party grazier. In terms of the latter option, the integration of DSL into other farming operations (particularly arable) has been significant in Selwyn Waihora (ECAN, 2014; The Agribusiness Group, 2012) and the wider Canterbury region (Dynes et al., 2010; Peel, 2013). The land use on these properties can be dynamic and is strongly dictated by the relative profitability and price margins of the various operations. In particular, grazier payments are strongly determined by the supply and demand of third party grazing for replacement stock and cow wintering (Postiglione, 2013). This research does not analyse these third party graziers and their integrated, diverse farming systems, and instead focuses on owned DSL.

3.2.1 Reasons for dairy support land purchase

Winter management of dry pregnant cows is integral to the success of the overall dairy farm system, as the body condition score (BCS) of cows at calving significantly impacts milk production, reproduction potential, and animal welfare in the following season (Roche et al., 2009). Quality replacement heifers are also fundamental to enhance the future performance of the MP. Consequently, the strongest motivator for farmers purchasing DSL is to achieve direct control of feed supply and the condition of livestock in the overall dairy system (Bennett, 2013; Davis, 2005; O'Connor, 2003; Postiglione, 2013; Richards, 2006). Bennett (2009) found that larger dairy farm systems in particular are more likely to purchase DSL in attempt to control external risk factors. Substandard experiences (for example growth targets not met and price volatility) with third party graziers often result in farmers deciding the risk of sourcing feed externally is too high (Dalley et al., 2008). This emphasises that the reasons for DSL ownership often relate to risk management benefits and the self-sufficiency of the overall farm system, rather than the rofitability of the DSL block. In other words, *"Control (is) king, cash flow certainly (isn't)"* (Richards, 2006, p. 50).

Secondary factors influencing DSL purchase include:

- Economic opportunities: Capital gains (Dalley et al., 2008; Richards, 2006); ability to raise surplus livestock (for example replacements and bull beef) (Dalley et al., 2008; O'Conner, 2003).

- Non-economic factors: Increased variety of tasks and change from routine of milking cows; new challenge to the management team; DSL is a 'hobby' farm (Dalley et al., 2008; Richards, 2006)

3.2.2 Factors driving successful dairy support land farms

Few studies investigate the factors which contribute to the success of whole DSL farm system, as research is generally focused on the success factors of the wintering component of the DSL system (Dalley, Edwards, Rugoho, & Stevens, 2011; Dalley, 2014). However, Bennett (2009) explored the factors driving successful outcomes of 17 DSL farms across regions in the South Island. The study found that there were three main drivers to DSL success, as follows:

- Adequate resources: Machinery; irrigation water supply; component staff; technical knowledge (of cropping, soil management, supplement production and raising heifers).

- Planning: Growing feed; silage harvesting; forage crop preparation and establishment; feed budgeting; management of cows moving to and from MP.
- Timing and attention to detail in critical tasks: Pasture management; silage cutting; crop establishment; fertiliser and spray applications.

In terms of location from the MP, Bennett (2009) concluded that smaller, adjacent support blocks effectively complement dairy farming systems and allow cost savings, while larger blocks (particularly those detached from the MP) may require an independent management structure and dedicated management and resources (i.e. labour and machinery) to avoid poor decision making and strain on resources.

3.2.3 Wintering systems

The main issue encountered by dairy farmers in terms of wintering their cows, particularly in the South Island, is the inability to grow sufficient pasture during winter to meet the energy requirements of the herd in late gestation (Dalley, 2011). Subsequently, *in situ* grazing of forage crops over winter off the MP is a common practice in the South Island (Dalley, 2011; Pinxterhuis et al., 2013). However, off-paddock structures such as wintering pad systems are increasingly advocated as an alternative wintering system to mitigate the adverse environmental effects associated with wintering cows (Beukes et al., 2011). In addition, case study research (Bennett, 2009; Richards, 2006) indicates that a number of South Island dairy farmers would prefer a pastoral wintering system, given their higher perceived performance in terms of milk production and BCS (Pangborn & Gibbs, 2009; Rugoho, 2013). However, this is a relatively uncommon option for South Island dairy farmers (Pinxterhuis et al., 2013), given the climatic conditions constraining winter pasture growth (Dalley, 2011).

3.2.4 Forage crop wintering systems

A typical DSL block in Canterbury consists of a dairy wintering system on forage crop (SIDDC, 2008; Richards, 2006), reflecting the crops ability to yield large tonnes of high quality forage on a relatively small area with less deterioration in nutritive quality relative to perennial ryegrass (Brown, Maley, & Wilson, 2007; de Ruiter et al., 2007; Judson & Edwards, 2008; Nichol, Westwood, Dumbleton, & Amyes, 2003). In current feeding regimes, the crops are generally break fed, using temporary electric fencing to divide the paddock into daily allocations based on dry matter yields and target allowances. Crop residues such as cereal straw or ensiled forages, are used to supplement the crop diet to provide an effective source of fibre and crude protein where the crop may be limiting (Judson & Edwards, 2008; Jenkinson, Edwards & Bryant, 2014; Nichol et al., 2003). Kale brassica crops have been widely used for wintering cows in Canterbury (Brown et al., 2007; Judson & Edwards, 2008; Nichol et al., 2003), while the popularity of fodder beet has rapidly grown in recent years (Chakwizira et al., 2013), largely due to advances in agronomy and feeding out management (Gibbs, 2014).

Fodder beet is a high yielding crop which produces between 18 and 35 t DM/ha (Matthew, Nelson, Ferguson, & Xie, 2011). Fodder beet (cultivar 'Rivage') was grown at the Ashley Dene Research Farm in 2012 and 2013 yielding 18.5 and 21.8 t DM/ha respectively (Edwards et al., 2014). Kale (cultivar 'Regal') was also grown on Ashley Dene at the same time and yielded an average of 14.6 t DM/ha (Edwards et al., 2014), which is in the expected range of 10 to 16 t DM/ha for the majority of kale grown in Canterbury (Judson & Edwards, 2008). Crop yields are highly variable, depending on cultivar selection, crop management and location (soil and climate) (Chakwizira et al., 2013; de Ruiter et al., 2009a; DLF Seeds, 2015; Gibbs, 2014; Judson & Edwards, 2008; Matthew et al., 2011). Edwards et al. (2014) found fodder beet had higher utilisation rates relative to kale (99.5% vs 85.5% respectively) in the same study trial. Agricom (2013) and Askin and Askin (2014) estimated that an average kale crop costs $800-1,200 and $1,223 respectively to establish, while a fodder beet crop costs approximately $2,000- 2,200 and $2,613 respectively. Both kale and fodder beet are relatively low cost feeds to grow at approximately 8.2 and 11 c/kg DM respectively (table 3) (Askin & Askin, 2014), however these figures are strongly dependent on crop yields. Therefore, yield is a significant determinant of the cost of production per kilogram of dry matter (de Ruiter et al., 2009a; Gibbs, 2014).

Table 3: Typical costs of production of irrigated kale and fodder beet crops. (Askin & Askin, 2014).

Land use	**Yield (tDM/ha)**	**Direct expenses ($/ha)**	**Cost of production (cents/kgDM)**
Kale	15	1,223	8.2
Fodder beet	23	2,619	11

In terms of their nutritional composition, both crops have a similar energy content (averaging 12.5 MJME/kg DM), however the crude protein (CP) and fibre (NDF) content is lower in fodder beet than that of kale (DairyNZ, 2012; Jenkinson, 2013), thus grass baleage, a moderate CP supplement, is often fed with fodder beet to raise the overall CP content of the diet (Edwards et al., 2014). Further, fodder beet bulbs are 40-60% sugar, hence are palatable and rapidly fermented in the rumen (Gibbs, 2014). Consequently, care must be taken to transition cows onto this feed gradually, to avoid rumen acidosis.

Forage availability and BCS of the dairy cow are integral aspects of dairy livestock management during the dry and prepartum period (Greenwood et al., 2011), particularly as BCS is correlated with reproduction, production and health parameters in the subsequent season (Edwards et al., 2014; Roche, et al., 2009). New Zealand guidelines recommend a target BCS of 5.0 calving for mixed age cows and 5.5 for first and second calvers (DairyNZ, 2012; Roche, et al., 2009), thus a common target is that cows gain over half a BCS unit over the wintering period, with many cows being dried off at a BCS of 4.5 (Judson & Edwards, 2008). However, evidence suggests that cows often fail to gain sufficient body condition when wintered on kale over this period (Greenwood et al., 2011; Judson & Edwards, 2008; Pangborn & Gibbs, 2009; Rugoho et al., 2014). Further, Edwards et al., (2014), Jenkinson (2013) and Keogh et al. (2009) reported that cows fed fodder beet over winter achieved higher BCS gains relative to those fed kale.

Judson and Edwards (2008) considered a number of reasons contributing to poor outcomes in relation to cow condition over 49 commercial kale crops in Canterbury and concluded inadequate crop allocation was the major driving factor. Further, Edwards et al. (2014) surveyed the BCS change of dairy cows grazing fodder beet, kale and kale-oat forage systems over winter and confirmed that the allocation of feed quantity is more significant in determining BCS gain rather than the type of crop or supplement fed. The findings are in agreement with Keogh et al. (2009), Rugoho (2013), Greenwood et al. (2011) who observed that cows which were offered a higher allocation of kale prepartum gained sufficient BCS units relative to those offered lower amounts.

3.3 Nitrogen leaching

3.3.1 The nitrogen cycle

Nitrogen is an essential element for plant growth and biological function (Di & Cameron, 2002a; Hatch, Goulding, & Murphy, 2002), however excess nitrates in freshwater bodies have the ability to degrade water quality (Di & Cameron, 2002a; McLaren & Cameron, 1996; PCE, 2013). Figure 7 illustrates a simplified nitrogen cycle on a dairy farm; the transfer of nitrogen from one form to another within the soil-plant-animal-atmosphere system.

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Figure 7: Simplified nitrogen cycle. (DairyNZ, 2013, p. 5)

In legume-based pastures and crops on dairy farms, biological fixation is an important source of plant available nitrogen (Di & Cameron, 2002a). Other sources of nitrogen include nitrogen containing fertilisers (de Klein, Monoghan, Ledgard, & Shepherd, 2010; Ledgard, Penno, & Sprosen, 1999) and imported supplements (DairyNZ, 2013a).

Within the cycle, nitrogen is converted to different forms that dictate the availability of nitrogen to plants and the transfer pathways of nitrogen. The amount of nitrogen cycling in a dairy system is dependent on several factors, with ingestion and deposition of nitrogen by the cow being a central component of the nitrogen cycle (Christensen, 2013; Moir, Cameron, Di, & Fertsak, 2011). Urinary nitrogen is largely in the form of urea, which is mineralised to plant available forms of nitrogen - ammonium (NH_4^+) and nitrate (NO^{3-}).

As seen in figure 8, not all of the nitrogen applied or fixed into the soil is assimilated by plants; a large proportion is incorporated into soil organic matter, or removed from the farm system as product, lost to the atmosphere, or lost to water. Nitrogen use efficiency[5] has been estimated to be between 25 to 50% at the farm level and around 15% for the individual cow (Ledgard et al., 1999), thus there are significant levels of excess nitrogen throughout the farm system which can be lost to the environment. The majority of nitrogen that is lost to water through surface runoff or subsurface drainage (leaching) is in the form of nitrate (NO_3^-) due to the highly soluble nature of the nitrate ions (Di & Cameron, 2002a; McLaren & Cameron, 1996).

3.3.2 Factors influencing nitrogen leaching on dairy support land

Nitrogen leaching occurs when there is an accumulation of nitrogen in the soil profile that coincides or follows a period of high drainage (Di & Cameron, 2002a). Both nitrate ions and soil particles are negatively charged, due to the same charges repelling one another, nitrate is not retained by the soils, and is subsequently prone to leaching during periods of high drainage (Di & Cameron, 2002a). Therefore, the amount of nitrate accumulated in the soil above the amount required for plant uptake, and drainage volume, are the two fundamental determinants of the amount of nitrate leached from the plant root zone (Cameron, Di, & Moir, 2013; Di & Cameron, 2002a).

The main factors affecting the level of nitrogen leaching losses are climatic season, soil properties and land use (Di and Cameron, 2002a). Typically, the primary driver of nitrogen leaching on dairy farms is urine deposition from grazing animals (DairyNZ, 2013a; de Klein et al., 2010; Di & Cameron, 2002a; Ledgard & Mennerr, 2005; Sharpley & Syers, 1979). In addition, forage crop wintering systems contribute to a disproportionately high amount of the total nitrogen leaching losses in dairy systems (Chrystal, Monaghan, Dalley, & Styles,

[5] Nitrogen use efficiency (NCE) describes the percentage of nitrogen inputs that are converted to nitrogen in saleable product (i.e. milk, meat) (nitrogen outputs) (DairyNZ, 2013).

2012; de Klein et al., 2010; Monaghan et al., 2007; Smith, de Klein, Monaghan, & Catto, 2008).

Climatic and seasonal conditions

In most areas of New Zealand, the majority of nitrogen leaching occurs in late autumn, winter and early spring; this usually when precipitation exceeds the rate of evapotranspiration and coincides with the soil being near or at field capacity (Di & Cameron, 2002a; Ledgard & Menneer, 2005; McLaren & Cameron, 1996). During these months temperature is at its annual low and therefore plant growth levels are minimal, leading to reduced nitrogen uptake by plants. In turn, nitrogen accumulates in soil profile, in concurrence with high rainfall and drainage (Macara, 2016), causing winter to typically be the period of greatest nitrogen leaching. Therefore, nitrogen released from mineralisation of soil organic nitrogen or from livestock urine deposition or fertiliser applications, in autumn and winter, is prone to direct leaching losses (Cookson, Rowarth, & Cameron, 2001; Di & Cameron, 2002a; Di, Cameron, Moore & Smith, 1999; Ledgard, Steele, & Feyter, 1988). For instance, Di et al. (1999) observed that nitrogen leaching losses of ammonium fertiliser applied in autumn were between 15-19%, while only 8-11% was leached from the equivalent spring applied fertiliser.

Soil profile and drainage

Soil texture and structure, thus soil infiltration capacity, governs the rate at which water drains through a soil profile, and therefore the rate at which nitrogen is leached from the soil (McLaren & Cameron, 1996; Webb et al., 2010); the more rapid the rate of subsurface drainage the less opportunity there is for plant uptake, denitrification or immobilisation to remove the nitrogen from the soil solution (Cameron, Di, & Condron, 2002). A number of studies have shown that profile available water (PAW)[6] has a significant influence on nitrogen leaching. For example, daily simulation studies of Canterbury soils have shown large increases of leaching is strongly correlated with decreasing PAW for grazed pasture (Green & Clothier, 2009) and for arable cropping (Brown & Zyskowski 2009). Lighter, sandy soils have a lower field capacity to store water and nutrients for plants than clay and silt

[6] PAW estimates the capacity of the soil to store water (and nutrients) available to plants, and is defined as the water stored between field capacity and wilting point, summed over the depth from soil surface to a depth of 60cm (Webb et al., 2010).

loam soils (Cameron et al., 2002), thus are prone to higher levels of nitrogen leaching under the same conditions. Artificial drainage systems have also been found to increase the level of nitrogen leaching, as they shorten the distance that nitrogen must travel through the soil (Di & Cameron, 2002a). For example a paddock with molepipe drainage leached 70 kgN/ha/year more than a similar paddock without artifical drainage (Scholefield et al., 1993).

Land use

Land use intensification increases nitrogen leaching losses (McLaren & Cameron, 1996); water quality in New Zealand catchments has generally declined due to agriculture intensification (Ballantine & Davies-Colley, 2009; Hamill & McBride, 2003; Monaghan et al., 2007). In terms of pastoral agriculture systems, Ledgard et al. (2009) found that the risk of nitrogen leaching increases exponentially with the total amount of nitrogen input; as systems become more intensified, inputs increase. Therefore, indigenous vegetation and extensively grazed pastures generally have low nitrogen leaching concentrations, while intensively grazed pastures, such as New Zealand pastoral dairy systems, typically leach large amounts of nitrogen, driven by high stocking rates and large nitrogen fertiliser applications (PCE, 2013).

Urine excretion: Dietary nitrogen and urinary nitrogen output

The nitrogen inefficiencies in grazed dairy systems are the excess crude protein (16% nitrogen) requirement of grazed forages relative to the dietary requirements of dairy cows, and the resultant excretion of excess dietary nitrogen in highly concentrated urine patches (de Klein et al., 2010; Eckard et al., 2010; Ledgard et al., 2000; Monaghan et al., 2007). Ledgard and Steele (1992) and Van Vuuren and Meijis (1987) found that approximately 20% of ingested nitrogen was retained in milk and liveweight, with the remaining 60% excreted as urine and 20% as dung, therefore urine deposition from grazing cows is a major component of the nitrogen cycle on dairy farms (Di & Cameron, 2002a). The nitrogen loading rate of urine patches is far in excess of what a plant can assimilate, therefore 8 to 20% of nitrogen applied in animal urine may be leached (Cameron et al., 2002; Silvia et al., 1999), which is highly significant when the nitrogen concentration in these patches is between 800 and 1,200 kgN/ha (Eckard et al., 2010). In contrast, nitrogen present in dung is typically slowly available in organic forms and hence dung is far less susceptible to leaching (Menneer, Ledgard, & Gillingham, 2004).

For a given soil type and climate, the nitrogen content, volume, frequency and distribution of urine is a key determinant of the level of nitrogen leached from pastoral dairy farms (Farrell, 2015; Romera, Levy, Beukes, Clark, & Glassey, 2012). Increases in nitrogen intake result in exponential increases nitrogen concentrations in the urine, particularly when intake exceeds 400gN/day (Castillo et al., 2000). In terms of urine patch distribution, modelling has indicated that overlapping (double) urine patches leach three times the nitrogen as a single patch (Shorten & Pleasants, 2007); thus high stocking rates are associated with high nitrogen leaching concentrations.

Figure 7 illustrates how grazing (i.e. urine excretion) is the primary driver of nitrogen leaching on a typical dairy farm, rather than applications of fertiliser or effluent. Direct leaching of nitrogen from fertiliser is generally low under best management practices for fertiliser use, as specified by the Fertiliser Code of Practice (FANZ, 2013), and therefore is not a significant source of nitrogen loss on New Zealand dairy farms (de Klein et al., 2010; Di & Cameron, 2002b; Ledgard et al., 1999; Monaghan et al., 2005). Further, the effects of fertiliser nitrogen use on nitrogen leaching are indirect in which increased nitrogen fertiliser inputs results in greater pasture production and therefore higher stocking rates incurring greater urinary nitrogen deposits (de Klein et al., 2010).

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Figure 8: Relative contribution of nitrogen sources to nitrogen leaching losses for a typical New Zealand dairy farm: grass/clover pasture, 3cows/ha, 150 kg fertiliser N/ha/year. (de Klein et al., 2010, p. 17).

Forage crop wintering systems

As aforementioned, urine excretion and climatic and seasonal conditions strongly influence the level of nitrogen leaching from a farm system; therefore, nitrogen losses from winter forage crops are exacerbated by high density urine patches associated with high stocking rates (~400 cows/ha/day) on crops, coinciding with low plant growth and nutrient uptake, and high rainfall and drainage (Dalley et al., 2011; Monaghan, 2012). Therefore, nitrogen losses from winter forage crops contribute to a disproportionately large proportion of nitrogen losses from the total dairy system (Chrystal et al., 2012; Dalley, 2011; Monaghan et al., 2007; Monaghan, 2012). For instance, in the case of the Waikakahi catchment in Southland, estimated nitrogen losses from the area occupied by dairy forage wintering systems were high relative to the area that they occupy and other land uses (as illustrated in figure 9) (Monaghan et al., 2007). Similarly, a trial (Chrystal et al., 2012) which modelled six farms identifed that although winter grazing represented only 4 to 9% of the total farm system area, it was responsible for 11 to 24% of the farms total nitrogen losses. On average, the winter forage systems leached around 58 kgN/ha/year which was nearly 2.5 times the level leached from the main pasture block (23 kgN/ha/year).

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Figure 9: Relative area occupied and predicted contribution to stream N load of the different modeled land uses within the Waikakahi catchment, Southland. (Monaghan et al., 2007)

Forage crop selection also impacts nitrogen leaching levels, as feeds with lower CP concentrations reduce dietary and urine nitrogen concentrations (Edwards, et al., 2014;

Farrell, 2015; Gibbs, 2014; James, 2015; Jenkinson et al., 2014). A trial (Jenkinson et al., 2014) conducted at the Ashley Dene Research Farm found that the nitrogen concentration in urine was 2.2 g N/L from non-lactating dairy cows fed fodder beet (10.9% CP) and pasture baleage (at 8 and 6 kgDM/cow/day respectively), while cows fed kale (13.8% CP) and green chop silage (11 and 5 kgDM/cow/day respectively) in the same experiment had a urine concentration of 2.4 g N/L. These results are consistent with those of Farrell (2015) and Ravera (2014); nitrogen intake was significantly greater for cows in the kale treatment, thus the urine nitrate content was also greater at 4.6-4.9 g/L compared with 3.7-4.0 g/L for cows in the fodder beet treatment. This suggests nitrogen leaching on a per cow basis is greater when cows are fed kale rather than fodder beet, relative to the CP content of the crops. However, despite the lower urine nitrogen on fodder beet, Ravera (2014) estimated that the fodder beet crop leached 1.44 times the level of nitrogen per hectare than the kale (78 vs. 54 kgN/ha/yr), and similarly, Farrell (2015) predicted fodder beet leached 1.5 times more nitrogen relative to kale (123 vs. 82 kgN/ha/yr). Both authors suggested the two reasons for the higher leaching losses on the fodder beet crop compared to the kale were twofold; average urine patch area was smaller (thus more concentrated) due to differences in soil surface microtopography (deeper foot prints in the fodder beet paddock as and the deep crater left from the bulb removal resulted in the urine pooling in smaller area), and secondly, the stocking rate was significantly higher on the fodder beet leading to higher urine patch coverage of the paddock.

Nitrogen leaching losses from forage crops are also impacted by pre and post-harvest management practices (Di & Cameron, 2002a). In particular, the time for residual soil mineral nitrogen to accumulate in the soil profile following cultivation in the preceding spring poses a high risk for nitrogen leaching in the winter (de Klein et al., 2010), as 50 to 70% of mineral nitrogen present in the soil in autumn is leached during winter under New Zealand conditions (Di & Cameron, 2002a). The periods of fallow in the autumn are important factors that influence the amount of nitrogen leaching (Fraser et al., 2013). For instance, Francis, Haynes and Williams (1995) showed that leaching losses were greater from March ploughing and fallow (72-106 kgN/ha) than the May ploughing and fallow treatments (8-52 kgN/ha) on a mixed cropping farm in Canterbury.

3.3.3 Nitrogen mitigation

A suite of mitigation options to reduce nitrogen leaching losses from intensively grazed pastoral systems in New Zealand have been reviewed by Menneer et al. (2004), Monoghan et al. (2007), de Klein et al. (2010), Vibart et al. (2015), and Howarth and Journeaux (2016). However, Perrin Ag (2015) notes that very few studies have reported on the cost and effectiveness of mitigating nitrogen losses from the overall dairy support farm system. Mitigation of nitrogen leaching typically focus on three main options: reducing nitrogen inputs; more efficient utilisation of nitrogen within the farm system; or capturing or re-using nitrogen before it enters waterbodies (de Klein et al., 2010). These options are likely to involve changes in land management practices, improvements in farm production efficiency, reductions in land use intensity, and/or land use change (Anastasiadis et al., 2012). Optimal abatement typically involves a combination of mitigation strategies (Doole, 2015). Understanding the effectiveness and cost of mitigation is integral to informed on-farm adoption of these strategies.

It is important to note that these mitigations will have differing effectiveness based on the farm they are applied on; there is no 'one size fits all' approach to mitigating nitrogen losses from farms, as these factors need to be considered on a farm specific and farm system basis (Howarth & Journeaux, 2016; Ledgard et al., 2006). In addition, natural biophysical factors such as soil drainage type, terrain and climatic conditions and natural waterbodies all influence the amount and type of nutrients lost, and significantly influence the effectiveness of nitrogen mitigation strategies (DairyNZ, 2013a).

The following mitigation strategies discussed in this section represent those applicable to DSL. The analysis excludes:

- Effluent management - this practice is unlikely to be undertaken on DSL, particularly those blocks detached from the MP.
- Alteration of stock classes and land use change - as this is not considered to fit the purposes of DSL.
- Culling livestock in autumn or improving cow genetics - as this will largely occur on the MP.

- Retiring productive agriculture land to reduce urinary nitrogen entering the soil profile and the nitrogen imported to the farm system – this not considered a rational economic option for DSL.

- Nitrification inhibitors, such as dicyandiamide (DCD), have been proven to delay the rate at which ammonium is converted into nitrate in soils, and thus reduce the risk of nitrogen leaching (Di & Cameron, 2002a, 2002b, 2003, 2004; McLaren & Cameron, 1996; Monagan et al., 2009; Smith et al., 2008). However, DCD is not a current mitigation option due to New Zealand product specifications prohibiting its use and is therefore not considered as a mitigation.

- Directly reducing the stocking rate: Reducing the stocking rate of DSL in turn reduces the nitrogen inputs, such as feed and fertiliser, that are required and means that there is less urinary nitrogen being excreted. However, on a DSL farm stock carried is directly proportional to revenue as grazing is often paid per animal. Therefore, while decreasing stocking rate would be likely reduce nitrogen leaching, due to its relationship with revenue means that for the purpose of this study it was not considered as a mitigation.

Nitrogen fertiliser use

Nitrogen fertiliser is regulary used on dairy farms to supplement clover fixation in order to increase pasture production and fill expected feed deficit gaps (Roberts & Morton, 1999). Direct leaching of nitrogen from fertiliser is generally low under best management practices for fertiliser use (see FANZ (2013)) (de Klein et al., 2010; Di & Cameron, 2002b; Ledgard et al., 1999). However, if fertiliser is not managed at best management practices nitrogen leaching can be mitigated by increasing use efficiency (for example optimise response rates) or by reducing the total volume of nitrogen fertiliser applied annually (DairyNZ, 2013a). Efficiently managing the fertiliser product, and the technique, rate, frequency and timing of application minimises the potential for nitrogen loss (FANZ, 2013; Selbie et al., 2013). Poorly timed nitrogen applications, particulary during autumn and winter, are least effective and prone to direct nitrogen leaching losses. For example, Cookson et al. (2001) found that autumn and winter fertiliser application of 50 kgN/ha under Canterbury conditions resulted in leaching losses of 23-42% of the nitrogen applied. Other research in Waikato with ^{15}N-

labelled urea fertiliser indicated that direct leaching can occur from applications in late autumn/winter, with losses up to one-third of nitrogen applied, due to low plant response rates (Ledgard et al., 1988). However risk of nitrogen fertiliser leaching can, to a large extent, be managed by good fertiliser practice (Shepherd & Lucci, 2011). The Fertiliser Association's Code of Practice for Nutrient Management lists best management practices and considerations for fertiliser use on pastoral land. For nitrogen these include applying fertiliser in split dressings (of 50 kg N/ha or less) when more than 200 kgN/ha per annum is applied and avoiding applications in winter when soil temperatures are low or waterlogged. These guidelines do not include recommendations on the maximum annual volume of nitrogen applications, however research has shown that nitrogen leaching losses can substantially increase when annual nitrogen inputs exceed 200 kgN/ha (Di & Cameron, 2000a; Ledgard et al., 1999; Ledgard et al., 2009). Reducing the volume of fertiliser used has the potential to decrease nitrogen losses, however this is likely to diminish pasture production. Plants have been shown to respond to larger amounts of fertiliser use, for example a trial in the Waikato (McGarth et al., 1998) found that plants responded to fertiliser application of up to 426 kgN/ha/year, although at larger volumes of fertiliser there were lower response rates. The reduction in pasture production will need to be compensated by either an increase in imported supplementary feed or a reduction in feed demand. Importing supplements will import additional nitrogen into the system, while reducing feed demand with fewer cows will reduce the urinary nitrogen available to leach from the farm system.

Winter forage crop management

The primary causes of nitrogen leaching from winter crops are mineralisation of soil organic matter following cultivation, urine nitrogen excretion, and timing and placement of fertiliser applications (Monaghan, 2012). Removal or reduction of winter crops would significantly reduce the overall nitrogen losses from a farm system, however winter cropping is an integral component of many dairy support systems in Canterbury, therefore this mitigation strategy may not be a rational option. Rather, nitrogen losses can be mitigated through GMPs; these include appropriate paddock selection which avoids waterways, hill terrain and soil pugging, leaving buffer zones around critical source areas (for example swales and gullies), and strategic grazing towards waterways (DairyNZ, 2013a). Other possible options to mitigate nitrogen leaching are to reduce the intensity of cultivation used to establish crops and to grow cover crops during the winter after forage harvesting (Di & Cameron, 2002a; Fraser et al., 2013). The choice of crop is also an important consideration; as the yield and CP content of the crops can determine the amount of urinary nitrogen deposited (refer to section 3.3.2), however, the total dry matter yield will need to be balanced in relation to feed demand.

Forage brassicas are highly responsive to nitrogen fertiliser application (de Ruiter et al., 2009b), therefore a significant withholding of nitrogen applications may lead to reductions in yield if soil mineral nitrogen is insufficient to meet crop demands. Given the relatively high cost of establishing these crops, farmers are likely to be unwilling to sacrifice yield and increase the average c/kg dry matter of feed in order to reduce nitrogen loss (Perrin Ag, 2015), therefore reducing nitrogen fertiliser use on crop land is unlikely to be a practical mitigation. However, it makes sense for farmers to optimise fertiliser nitrogen usage, applying only the necessary amounts to achieve optimal yields and effectively utilising any existing mineralised soil organic nitrogen first.

Physical disturbance of soil by intensive tillage can promote rapid mineralisation of soil organic matter by improving aeration and making aggregate protected organic matter accessible to microorganisms, however there is currently inconclusive research into whether direct drilling is able to reduce nitrogen leaching (Fraser et al., 2012). Some international studies have found that mineral nitrogen loss can be mitigated by employing minimal or no tillage establishment techniques (Colbourn, 1985; Meek et al., 1995). In contrast, a field experiment conducted on poorly drained soil in Canterbury found tillage did not have a significant impact on nitrogen leaching from grazed winter rape (Trolove, Thomas, Clemens, & Beare, 2016). It is worth noting that minimal tillage may not be suitable for some paddocks, or crops, for example fodder beet.

Research has shown that the use of winter cover crops after forage harvesting can effectively reduce nitrogen leaching, through uptake of residual nitrogen, which is otherwise vulnerable to leaching during the fallow periods (Carey et al., 2016; Di & Cameron, 2002a; Fraser et al., 2013; McLenaghan et al., 1996). McLenaghan et al. (1996) showed in a New Zealand study that the nitrogen leaching loss under a ryecorn cover crop was 2.5 kgN/ha compared with 33 kgN/ha for bare fallow soil. Likewise, an extensive literature review of Canterbury cover crops found that relative to fallow treatments, cover crops reduced nitrogen leaching by 50% on average, however this was highly variable largely due to to sowing date, weather and soil PAW (Teixeira et al., 2015). Carey et al. (2016) found that sowing a cover crop of oats following winter dairy grazing of kale decreased nitrogen leaching losses by about 34% on average (range 19-49%) over the winter and spring period on the Ashley Dene Research Farm. The study found that the sooner the cover crop was sown following crop harvest, the greater the uptake of nitrogen by the cover crop, thus the greater the reduction in leaching losses.

Diet manipulation

Crude protein (CP) content in the feed source influences the nitrogen concentration in the excretion from an animal, which in turn impacts nitrogen leaching. Increasing interest has developed in the role of alternative plant species in altering the protein intake of dairy cows and ultimately mitigating nitrogen. Extensive research has showed lower total urinary nitrogen excreted from dairy cows consuming diverse pastures (consisting of mixtures of ryegrass, herbs and legumes) compared with those consuming standard ryegrass-clover pastures, largely due to the lower CP content and greater winter daily nitrogen uptake rate of diverse pastures (Box, Edwards, & Bryant, 2016; Beukes et al., 2014; Edwards, et al., 2015; Malcom et al., 2014; Totty et al., 2013). Farm system modelling suggests that diverse pastures have the potential to reduce nitrogen leaching from Waikato dairy farms by 11% to 19% depending on the proportion of the farm sown, 20% or 50% respectively (Beukes et al., 2014). Winter forage crops, namely kale and fodder beet, also have low CP content relative to ryegrass-clover pasture, resulting in lower total urinary nitrogen excreted per cow (Farrell, 2015; Ravera, 2014). Consquently, in terms of reducing nitrogen leaching from forage crops during winter, the low CP concentrations of kale and fodder beet leaves little scope to reduce urinary nitrogen excretion further through dietary manipulations (Edwards et al., 2014; Miller, Bryant, & Edwards, 2012).

Supplements with low CP content, such as cereal silages and wheat, may be an effective feed source to mitigate nitrogen, particulary if they substitute autumn feeds that have a relatively high CP content. For instance, Ledgard et al. (2006) found that cows fed maize and cereal silage had significantly lower total urinary nitrogen excretion relative to cows fed pasture and lucerne silage. However, DairyNZ (2013a) and Monaghan (2014) advise that diet substition to reduce overall nitrogen inputs to a farm system is likely to have a relatively small impact unless large amounts of low CP supplements are used. There are also other considerations for this mitigation, such as animal health, feed availability and the cost-effectiveness of supplements on the basis of metabolisable energy.

Off-paddock structures

A range of off-paddock structures, such as wintering barn systems and stand-off pads, can be incorporated into the farm system to mitigate nitrogen loss. A wintering barn is a structure where cows are fully fed and housed indoors over the winter months (Journeaux, 2013), whereas a winter stand-off pad system involves removing cows from paddocks after a specified grazing time to a pad (Brown, 2014; Christensen et al., 2010). In terms of nitrogen mitigation, these structures provide the greatest benefit when they capture and store effluent during high risk periods for leaching (autumn and winter), and apply it evenly to soil at a time and rate which matches plant demand (Beukes et al., 2011; Brown, 2014; Christensen et al., 2010). Other environmental benefits of off-paddock structures include better feed utilisation and reduced damage to saturated, poorly drained soils (Christenson, 2013; Journeaux, 2013).

Journeaux (2013) reported that in a wintering barn system, nitrogen leaching levels can be reduced by a third, relative to pasture systems, through the collection of effluent and application at appropriate times. Another study in which cows were housed all year round found that nitrogen leaching was reduced by 55-65% (de Klein & Ledgard, 2001). However, these fully housed systems have significant capital costs (Beukes et al., 2011; Newman & Journeaux, 2015), thus high financial returns are required in order to meet debt repayments. A cost benefit analysis conducted by Newman and Journeaux (2015) suggested there is conflict between the profitability of winter barn systems and their ability to reduce nitrogen losses, as some farmers will often intensify their system to justify the cost of the structure which inadvertently eliminates any reduction in nitrogen loss that may have otherwise occurred.

The use of winter stand-off pads in conjunction with duration controlled grazing practices reduces the amount of time that cows spend in the paddock and the quantity of urinary nitrogen deposited in paddocks, and hence has been shown to mitigate nitrogen leaching by 35-50% (Christensen et al., 2010; de Klein & Ledgard, 2001; de Klein et al., 2006). Brown (2014) modelled a stand-off pad wintering system which restricted fodder beet grazing to six hours as an alternative to the current Lincoln University Dairy Farm fodder beet wintering system. This analysis concluded that stand-off system leached 58% less nitrogen relative to the current system, however it was 83% more expensive. To reduce the significant capital costs of structures, Chrystal et al. (2016) have proposed a low-cost portable stand-off facility with an effluent liner to reduce nitrogen leaching from winter forage crops. Overall, the ability of structures to mitigate nitrogen leaching is largely dependent on how they are incorporated in the system and the design of the effluent system, while their capital cost is significant and depends on what type of structure in constructed.

Irrigation management

Irrigation's effects on nitrogen leaching are complex (Selbie et al., 2013). For instance, the uptake of urinary nitrogen deposited on pasture may be increased by irrigating in dry periods, which will reduce the leaching risk. However, irrigation increases the carrying capacity of the land as more pasture will be grown, consumed and excreted on, which in turn will increase the risk of additional nitrogen leaching in comparison to an unirrigated block. Furthermore, leaching will be increased if irrigation is not scheduled correctly or the irrigation type is inefficient (for example borderdyke irrigation (Moore, 2002)), and soil water content exceeds field capacity. Soil moisture monitoring is required for irrigation scheduling; to ensure the application depth and rate of return provide sufficient moisture to enable plant growth, while avoiding excess drainage and subsequent nitrogen leaching. Variable rate irrigation (VRI) is a recent development that aims to optimise scheduling according to soil differences and plant requirements using software driven irrigation with individual sprinkler control. Hedley et al. (2010) found this method effectively reduced soil water drainage by 16 to 33% during the irrigation period at a trial in Ashburton. If irrigation is used in such a way that the added water does not cause excess drainage then there should be no risk of additional leaching from irrigation (DairyNZ, 2013a). Removing irrigation would make some farm systems unviable in their current form, while changing to a more efficient irrigation type or VRI is a significant capital investment and may help mitigate nitrogen leaching if irrigation was previously being used inefficiently.

Stock exclusion from waterways and riparian buffer zones

Fencing waterways is widely promoted as GMP to reduce the direct deposition of urinary nitrogen into waterways (DairyNZ, 2015; ECAN, 2014). Riparian planting, grass filter strips and wetlands generally provide a low benefit mitigation option for nitrogen leaching (Monaghan, 2014). Soluble nutrients, such as nitrates, are removed via microbial denitrification augmented by plant uptake and accretion in sediments (Parkyn, 2004). The effectiveness of these features for removing nitrogen varies considerably, depending on their ability to intercept and modify flow pathways (de Klein et al., 2010). Parkyn (2004) extensively reviews literature regarding the efficiency of riparian buffer zones, and concludes that most of the difference in studies of nutrient removal inefficiencies can be explained by site-specific variability in the characteristics of the buffer (width, type and maturity of vegetation) or in characteristics of the surrounding land (soil type, terrain). This study also suggests that a presence of a riparian buffer may be ineffectual at reducing soluable nutrient levels (other than through exclusion of stock) if the soils are well drained, thereby the soluble nutrients bypass the riparian buffer (Parkyn, 2004).

3.4 Farm systems modelling

Whole farm system theory is a holistic study on the various components contributing to the farm system as a whole. This approach emphasises the complex interactions between various elements of the biological farm system. An adjustment to one component may change the overall physical, financial and environmental performance of the farm system. The purpose of farm systems modelling is to examine how a change to one component of the system may impact the rest of the system, for example nitrogen reductions.

The objective of the farm systems modelling used in this research is to construct abatement cost curves; to define the financial cost of achieving a given level of nitrogen loss mitigation in a given context, in this case on farm (Doole, 2012). Abatement cost curves are extensively used because of their clear and concise explanation of both abatement and cost dimensions in a graphical framework (Radermacher, Riege-Wcislo, & Heinze, 1999). For the purposes of this research, economic and nitrogen loss changes are required to create an abatement curve, and a biophysical model is integral to ensure feed supply and demand is balanced at each point on the abatement curve (Muller, 2015). Currently, there is not a model which incorporates a biophysical farm system, nutrient losses and the economic performance of a farm. However, it is worth noting that the alignment and integration of Farmax and Overseer is a high priority for both companies (McEwen, 2015; Overseer, 2016). Many consultants and researchers throughout New Zealand have used both Overseer and Farmax to create cost abatement curves for farmers, regional councils, industry bodies, and research institutions (Vogeler et al., 2014). With respect to nitrogen regulations, this modelling approach is of value to help inform regional councils of the on-farm implications of various proposed policy and allocation options, as required by section 32 of the RMA.

3.4.1 OVERSEER™ nutrient modelling

Overseer™ is an agriculture management support tool that examines the impact of nutrient use and the flow of nutrients within a system, as well as greenhouse gas emissions, to optimise production and environmental outcomes (Selbie et al., 2013). The model uses a budgeting approach that measures nutrient inputs, transfers and outputs based on the information specific to an individual farm (Cichota & Snow, 2009; Wheeler et al., 2003; 2006). While the initial purpose of Overseer was to support fertiliser and nutrient management on pastoral farms, Overseer is being increasingly used to implement regional policy and regulations in relation to nutrient losses from agriculture (Cichota & Snow, 2009; Williams et al., 2013). For instance, nutrient limits within the LWRP and Variation 1 are set on the basis of Overseer (ECAN, 2015). For policy purposes, the reason for using a farm systems modelling approach is that direct measurement of nitrogen loss is impractical, costly and time consuming, given the scale and variability of farm systems (Addiscott, 1995; Duncan, 2014b; Shepherd et al., 2013). Overseer model is generally regarded as the most accurate tool for estimating nutrient losses across the diversity and complexity of farming systems in New Zealand (Doole, 2012). Matthew, Horne and Baker (2010, p.292) described Overseer as the “software of choice for predicting nitrogen leaching losses” for the dairy industry, farm consultants and many regional authorities. By quantifying nutrient losses at the farm level, Overseer allows regulators to adopt effects-based (i.e. output based) policy and regulations rather than rules based on input controls, which are inherently more inefficient with respect to their impact on farm productivity (Journeaux, 2016; Murray et al., 2016). Overseer is extensively used to evaluate the effectiveness of different mitigation practices (Journeaux, 2016; Shepherd, et al., 2013; Wheeler, Ledgard, & Monaghan, 2007).

Empirical relationships, existing farm information and internal databases are used in the Overseer to estimate nutrient inputs and outputs, and in turn calculate nutrient losses at the block and farm scale (Ledgard et al., 1999; Shepherd et al., 2013). Validation has shown Overseer to provide a reasonably accurate representation of nitrogen leaching loads of New Zealand farming systems (Parfitt, Mackay, Ross, & Budding, 2010; Ledgard et al., 2006; Wheeler, van der Weeden, & Shepherd, 2010). However, there is less certainty about the use of Overseer in regards to phosphorus (Gray, Wheeler, McDowell, & Watkins, 2016) as well as the nitrogen lost from arable crop rotations (FAR, 2013) and winter fodder crops (Farrell, 2015). Further, the use of Overseer for regulator compliance is recommended to be approached with caution (Cichota & Snow, 2009). Models that are continually evolving, such as Overseer, are generally better at describing relative changes, as opposed to providing the absolute value of leaching; thus it is recommended that policy emphasises the relative changes rather than the absolute output (Cichota & Snow, 2009).

The key assumptions underpinning the Overseer model are that: the system is in quasi-equilibrium (inputs and farm management practices commensurate with farm productivity); it uses long-term annual averages (i.e. the model assumes a “steady state”); the user supplies actual and reasonable inputs; and many GMPs have been implemented on the farm (Shepherd et al., 2013). Overseer also assumes that the farm is biologically feasible, for example, nutrient mitigation scenarios include changes in farm productivity (Wheeler et al., 2007). Therefore, Overseer is best used in conjunction with other models, to ensure the various mitigations applied are biologically feasible. Despite the concerns regarding the assumptions and the accuracy Overseer, it is considered the best tool available and will continue to be mandatory for the regulation of nitrogen leaching on Canterbury farms.

3.4.2 FARMAX® Professional

Farmax® Pro is a decision support software designed to assist the management of New Zealand farm systems. The farm-scale simulation model is a whole-farm decision support model that uses monthly estimates of pasture growth, farm and stock information to determine the outcomes of managerial decisions on production and financial performance (Bryant et al., 2010). Farm systems and economics models, such as Farmax, ensure a biologically feasible scenario is being represented and allow users to evaluate the financial implications of alternative farm systems and management changes. Energy intake is a key foundation of the model, therefore the pasture covers predicted from the balance of whole-farm feed supply and demand must be biologically feasible at all times (White, Snow, & King, 2010)

Farmax is a useful software to model an existing farm system and the potential impacts of different nutrient mitigations on profitability (Allen, 2012). The model has been widely used by consultants and industry bodies to create nitrogen abatement cost curves for pastoral farming in New Zealand, especially in conjunction with Overseer (for example DairyNZ Economic Group, 2015; Kaye-Blake et al., 2014; Smeaton et al., 2011; Vibart et al., 2015; Vogeler et al., 2014). One of the limitations of Farmax is it does not account for interest rates and the capital costs of mitigations, for example the capital costs of a winter stand-off pad (Allen, 2012). Another limitation is Farmax is not an optimisation model; with simulation models (such as Farmax) the definition of optimal resource use requires the user to iterate their way to an optimal solution, which is time consuming and not always reliable (McCall, 2013)

3.5 The cost of nitrogen mitigation

In recent times, the financial impact and cost-effectiveness of on-farm nitrogen mitigations has been the subject of several New Zealand studies, particularly dairy farm systems. In light of the NPSFM consultants, researchers and industry bodies have modelled the impact of nitrogen policies on farm profitability, using Overseer and Farmax (for example DairyNZ Economics Group, 2015; DairyNZ, 2013b; Kaye-Blake et al., 2014; Perrin Ag, 2015; Smeaton et al., 2011; Vibart et al.,2015; Vogeler et al., 2014). These studies have consistently indicated that the relative change in nitrogen leaching and operating profit for any given mitigation is inherently different for each individual farm system. This section discusses the few studies that have focused on the cost of mitigating nitrogen from the overall dairy support system.

DairyNZ (2013b) assessed the impact of nutrient allocation limits being set in the Waituna catchment in Southland, using Farmax and Overseer modelling. Two DSL farms were modelled and a combination of mitigations were used to reduce nitrogen leaching by 10, 20, 35 and 50%. This included reducing the volume and rate of nitrogen fertiliser, reducing or removing crop area, changing the crop cultivation technique, feeding supplements with low CP content in autumn, decreasing stock numbers, constructing off-paddock wintering structures, and lifting winter crop and feeding it out. The DSL farms experienced the greatest reductions in operating profit on average relative to other farm types, with the 25% nitrogen reduction scenario resulting in a 46% decrease in farm profitability (earnings before interest and tax (EBIT[7])), and further reductions leading to the farms being no longer viable. The profitability of DSL was heavily dependent on winter grazing, which suggests mitigation strategies aimed at winter grazing will have significant financial risks to DSL businesses. The study concluded that the response of individual farms to different nitrogen reduction scenarios was highly variable due to the differences in system type, existing leaching rates, soil type, stage of development and farm management practices. However, the specific characteristics of the DSL systems used in this report were ambiguous, limiting the transferability of the findings to other DSL farmers looking to make changes on their farms.

Perrin Ag (2015) was contracted by the Waikato Regional Council to quantify the financial cost of mitigating nitrogen over eleven case study DSL farms in the Upper Waikato. These farms covered a range of soil types, dairy support enterprises and feeding regimes; on average 77% of the livestock carried represented dairy support classes and 7% of the effective farm area was winter crop. Two nitrogen reduction scenarios (10% and 20%) were modelled using Farmax and Overseer. For the 10% nitrogen loss reduction scenario, on average, the area planted in winter crop was reduced by 56%, stock numbers were reduced by only 1% and fertiliser nitrogen applications to pasture were reduced by 8%, and in turn imported feed use increased by 64%. For this scenario, the average change in farm operating profit was a reduction in EBIT of 2.9% per hectare. Under the 20% reduction

[7] EBIT = revenue less operating expenses adjusted for changes in livestock numbers and values and depreciation

target, the area planted in winter crop reduced further to an average of 65% of the current area, stock numbers were reduced by 10% and fertiliser nitrogen applied to pasture was reduced by 35%, resulting in a 90% increase in imported feed use. The average change in operating profit in achieving the 20% reduction target in nitrogen leaching was 7% per hectare (excluding one outlier farm), however, the range of EBIT changes varied significantly between individual DSL farms, due to their different soils and management practices. The nitrogen mitigations used in this study focused on replacing nitrogen grown pasture and winter forage crops with imported supplements, and therefore the impact of these mitigations is largely dependent on the prices of inputs such as fertiliser and imported supplements.

A similar case study conducted by Everest (2013) also examined the impact of nitrogen mitigations on operating profit (EBIT) on two dairy support farms in the Hinds catchment using Farmax and Overseer. Both farms were located on light to very light soil, were 100% irrigated with a range of irrigation types (including borderdyke), and grazed the MPs replacement calves and heifers all year, and wintered cows on kale and fodder beet. In addition, both farms grew cereal grain, while one farm grew maize silage. A wide range of mitigations outside Overseer were modelled using assumptions derived from scientific literature. These include precision agriculture technologies, such as the installation of soil moisture monitoring and VRI, using crop yield maps to define fertiliser use, and variable rate fertiliser, as well as diverse pastures, and nitrification inhibitors. On average, these mitigations resulted in a 50% reduction in nitrogen leaching and a 11.7% reduction in EBIT. However, this modelling was subject to a range of assumptions, for instance, it was assumed that farmers had the skill to effectively adopt precision agriculture technologies and DCD would become available to dairy farmers. In addition, capital intensive mitigations including the use of wintering barns and the conversion of borderdyke irrigation to centre pivot were considered, which resulted in significant reductions in nitrogen leaching (-62.8% to -84.1%) and relatively smaller reductions in profitability (-0.4 to -41.2%). However, it is important to recognise that these mitigations require significant capital investment, suggesting that other mitigations which are less capital intensive may be more financially feasible.

Overseer and financial modelling of nitrogen mitigation strategies was also undertaken on 18 farms representive of land use in the Selwyn Waihora catchment, including two irrigated dairy support farms on light soil types (The Agribusiness Group, 2012). Two mitigation strategies were considered for DSL – efficient irrigation scheduling and DCD use in May and August. Efficient irrigation scheduling showed the greatest (40%) reductions in nitrogen leaching, with a reduced net cash position and total equity. DCD use resulted in relatively small (3%) reductions in nitrogen leaching, operating surplus and net cash position, however this is currently not a mitigation option due to product specifications.

The above literature indicates that nitrogen mitigation, as required under Variation 1, are likely to have significant implications on the operating profit of DSL, however the extent is largely determined by the mitigations adopted, farm management practices, farmer preferences, biophysical factors (soil and climate), and the farm's nitrogen leaching relevant to the 15 kgN/ha/year threshold in Variation 1.

3.6 Summary of literature review

Dairy support is an integral component of dairy operations, to support the MP by wintering cows, growing supplementary feed and raising young stock. The main reason of DSL ownership is to attain direct control of feed supply and livestock condition, which enhances the overall success of the total dairy operation. However, there is a lack of literature on the performance levels achieved by dairy support operations. Wintering on forage crops is a common practice on DSL in Canterbury. However, this practice can contribute to a disproportionately high amount of the total nitrogen leaching losses from the system, driven by high stocking rates, low plant nutrient uptake and high soil drainage. Regional authorities have developed, or are developing regional plans to maintain or improve water quality in New Zealand. A key aspect of these plans is the implementation of nitrogen loss limits for agriculture land. Consequently, DSL farmers are under significant pressure to implement a system that meets the nitrogen constraints. The literature has identified a suite of options to reduce nitrogen leaching losses from intensively grazed pastoral systems. Many consultants and researchers throughout New Zealand have used farm system modelling to create cost abatement curves; to define the financial cost of achieving a given level of nitrogen loss mitigation on farm. However, research to date has largely excluded consideration of the implications of nitrogen mitigation on dairy support systems, suggesting this is area not well understood.

Chapter 4
Methodology

4.1 Research approach

This research uses a multiple case study approach (Yin, 1984, 2013) to analyse the implications of mitigating nitrogen losses from DSL, in context of the conditions and constraints unique to each individual farming system. In contrast to using industry averages, or a survey, a case study approach allows for in-depth, holistic analysis, and encourages a diversity of rich information that is required to fulfil the purposes of this research.

4.2 Selection of the case studies

Four case study farmers were selected using purposive sampling. Patton (1987, p.52) described purposive sampling as selecting "information rich" cases which have insight to the research questions, while Turner (2010) suggests cases should be selected based on their willingness to openly share credible information. Further, in order to limit potential bias from the small number of cases and allow the "triangulation of subjects" (Myers & Newman, 2007, p.1) there should be maximum variation between cases (Perry, 1998; Eisenhardt & Graebner, 2007).

Selwyn Waihora catchment has a range of soil and rainfall types, as well as a variety of DSL systems. In obtaining information 'rich' case studies, a strong emphasis was placed on selecting dairy farmers that offered diversity in terms of catchment biophysical (soil type) and farm system characteristics (crop and stock types, irrigation type, and absolute scale of the farm). This was considered important, given the small number of farmers studied and the heterogeneity inherent in DSL practices in Canterbury (Richards, 2006). Agriculture lecturers at Lincoln University acted as key informants in selecting case study participants according to the following criteria:

- The farmer owns a MP and DSL within the Selwyn Waihora catchment
- The farmer has access to robust physical, environmental and financial farm information

- The DSL farm provides diversity to other case studies, in terms of regional biophysical and management characteristics

4.3 Data collection

For the purposes of this research, data collection was in the form of personal interviews. Interviewing was considered the best method due to the quantity and detail of information required (Sekeran & Bougie, 2013). The interviews took place at the farmer's property, and generally lasted approximately two hours. Further questions and verifications were completed over the phone or email.

The interview guide (Appendix 1) provided structure to the interview and ensured that all required information was gathered. The first section of the interview was structured with quantitative questions pertaining to the management practices of the farm system and financial information. Farm data collected was based on the 2015-16 season and the wintering period in 2016. It was essential that the farm input data required for the Overseer and Farmax modelling was collected during this stage. The second section was semi-structured and focused on gathering in-depth, rich qualitative information, to understand the context of the farm system and the views of the farmer. The semi-structured section was designed to involve a balance of structure and flexibility, in which a combination of predetermined and improvised questions were asked. Unlike structured interviews, this method allows the researcher the flexibility to adapt probe questions based on the responses to their questions (Myers & Newman, 2007). The interviewer can therefore tailor their questions to the interview situation, taking advantage of the uniqueness of the specific case (Eisenhardt & Graebner, 2007). This mixed methods approach is a unique strength of case study research, as the collaboration of qualitative and quantitative data strengthens and validates the overall findings, and enables triangulated evidence (Yin, 1984; Eisenhardt, 1989).

The interview was recorded and brief notes were taken during the interview to aid the questioning. All the farmers provided farm maps to support the contextual understanding of their DSL farm, and how it was intergrated with the MP. In most cases, fertiliser budgets, soil tests and financial budgets were also provided. Audio recordings allowed the exact quoting of farmer responses. All information collected in the interviews was subsequently transcribed and used to create individual case study profiles. Each draft profile was sent to the individual farmer, to ensure the data was correctly intepreted.

4.4 Confidentiality Issues

Initial contact with farmers was by an email outlining the purpose and importance of the research. A subsequent phone call was used to ask the farmers if they were willing to participate and to arrange an interview. Provided the farmer agreed, a following email was sent to them including a research information sheet, consent form, and the interview guide. Confidentiality matters were addressed at the beginning of the interview, in which every farmer was assured that all disclosed information was confidential and would not be identifiable back to the individual farmers. The farmers were also asked for permission to audio record them. In order to ensure anonymity, each farmer was assigned a letter (for example Farmer C) to be used throughout this research. Although significant efforts have been made to avoid readers from identifying the farmers or the property, the author acknowledges that these privacy efforts may become void in circumstances where the reader is a close acquaintance with the particular farmer.

4.5 Quantitative research methods

4.5.1 Modelling process

Overseer (Version 6.2.3) and Farmax Professional (Version 7.1.0.31) were used simultaneously to create a nitrogen abatement curve[8] for each case study farm. Farmax ensured that the farm system created was biologically feasible (feed demand and supply are balanced) and allows the financial implications of mitigation to be analysed, while Overseer allowed the current farm systems nitrogen loss and the impact of mitigation strategies to be analysed (refer to section 3.5).

The Overseer files were created for each case study farm based on the best available farm data provided by the farmer for the 2015-16 season (including the 2016 wintering season). This data was smoothed to represent a reasonably average season as Overseer is designed

[8] Due to the few points produced for each farm from the modelling (i.e. base farm and 22% reduction scenario under Variation 1) the points have not been joined to form an abatement 'curve'. However, the dots still describe the theory behind abatement curves; the cost of achieving a given level of nitrogen loss mitigation, and therefore will be continued to be referred to as an abatement curve.

to model a long-term steady state (Shepherd et al., 2013). All files were created using the relevant Overseer Best Practice Data Input Standards (referred to from hereafter as the Overseer Input Standards). The Overseer Input Standards help to ensure that files are created in a consistent and transparent way and assist comparability between files (Roberts & Watkins, 2014). Generally, Overseer assumes that GMPs have been implemented. For example, if fertiliser is applied, Overseer assumes that the stated rate is applied evenly across the application area. Similarly, the model assumes that stock are excluded from all waterways and streams. Further, Variation 1 requires DSL farms to reduce their nitrogen losses by 22% beyond GMP, therefore the files were set up consistent with the assumption that farms were operating at GMP. It is important to note that the GMP assumed in Overseer are different to the GMP in Variation. Therefore, for the purposes of this research, GMP has been defined in accordance to Variation 1 (refer to Schedule 24 of the LWRP) as:

- Fertiliser is applied in accordance with the Code of Practice for Nutrient Management (2007).
    - No fertiliser applications in June and July
    - No more than 50 kg of nitrogen applied per hectare in one month (can be multiple applications as long as the sum of all applications in one month are under 50 kgN/ha).
- Irrigation applications are undertaken in accordance with soil moisture monitoring, a soil water budget, or an irrigation scheduling calculator.

In addition to the GMP above, this study also assumed a cost of $2,500 for nutrient budgets and farm environmental plans per farm. While this cost is likely to vary year to year, it will be important that farmers can demonstrate that GMP is being met and that they are meeting their Variation 1 requirements. Despite the possible yearly variation in this cost, an average yearly cost was assumed.

The base farm systems constructed in Overseer were then used to develop the base Farmax files, to ensure the farm system was biologically feasible. The long-term mode was used for the purposes of this research; to ensure the farm is a viable system following the implementation of the mitigations. Therefore, the farms were modelled in a steady state in terms of opening and closing stock numbers, stock weights and pasture covers. If Farmax indicated the system was infeasible, appropriate adjustments were made to the Farmax and Overseer file following further clarification with the farmer. Some of the financial data provided by the farmer was also imported into Farmax (refer to section 4.5.3 for financial assumptions).

Figure 10 illustrates the systematic mitigation modelling process that was used to create the abatement curves for each case study farm. The aim of modelling mitigations for nitrogen leaching was targeting the 22% reduction (beyond GMP) required under Variation 1. Once baseline farm models had been developed in Overseer and Farmax, a standardised sequential nitrogen loss mitigation protocol (refer to section 4.5.2) was applied iteratively to each farm until the targeted nitrogen reduction from the base farm were achieved. Each case study farm followed the same overall process; however, there were subtle differences in the mitigation strategies between farms due to their individual farm characteristics. For the purposes of modelling efficiency, nitrogen losses of +/- 20% that were around the percentage target were accepted for individual case study. The possible amount of iterations required to precisely achieve the target were likely to add little value to the analysis. An average per farm reduction of 23.7% was achieved through the modelling process (excluding Farm B which only require an 18.5% reduction due to its low baseline).

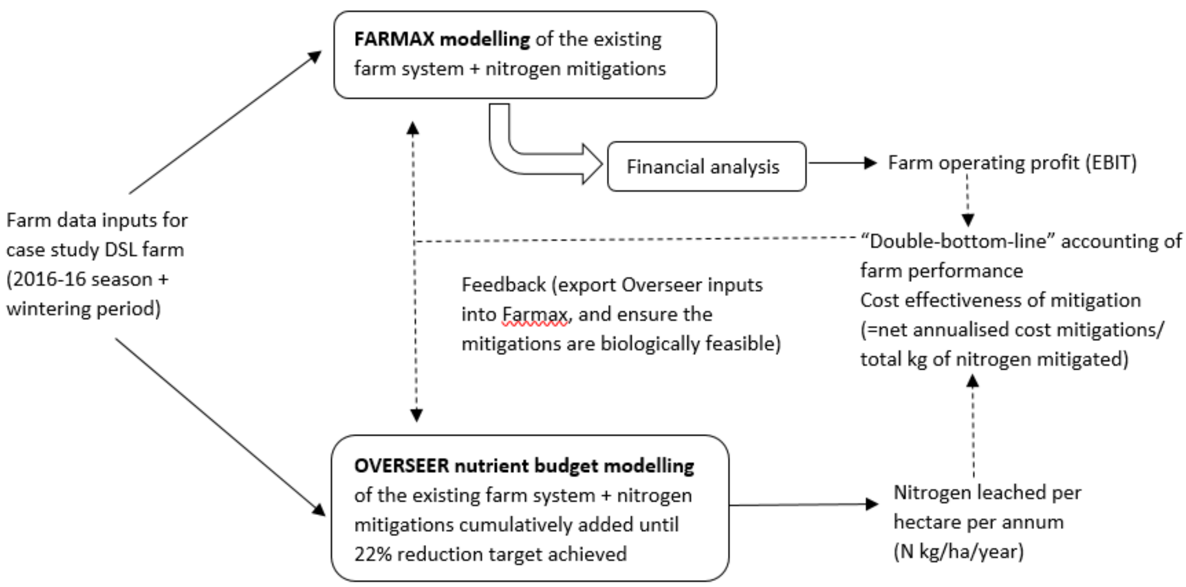

Figure 10: A systematic diagram of the mitigation modelling process.

The mitigation modelling stopped when the reduction targets were achieved or if the farm got to the point where land was retired, as defined as having annual pasture surplus that was either sold or stored indefinitely. The results from these mitigation options were then analysed, particularly the impact on annual profit (measured by EBIT), production and nitrogen leaching. For the purposes of this project, operating profit and nitrogen loss are analysed on a per hectare per annum basis, to allow a consistent, comparative analysis between farms. In addition, Variation 1 requires a 22% reduction in nitrogen loss per hectare, therefore it is considered an appropriate indicator for this research. These points were used to create abatement curves; to estimate the impact of relative change between nitrogen leached and farm operating profit per hectare from the original base point for each case study farm.

4.5.2 Mitigation strategies

The mitigation strategies were chosen according to the following criteria:

- The mitigation is the most cost-effective method to reduce nitrogen leaching from a DSL farm system
- The mitigation is able to be incorporated into a DSL farm system in a practical manner, with the farmer maintaining the same level of skill
- The mitigation is recognised by the current Overseer model.

A review of the literature on nitrogen mitigation options (refer to section 3.3.3), discussions with experts and the case study farmers, as well as preliminary Farmax and Overseer modelling, acted as key information as to which mitigation options were selected. In particular, the chosen mitigations and process is broadly consistent with those employed by the DairyNZ Economics Group (2015) in their report which models the financial implications of reducing nitrogen loss on nine case study dairy farms within the South Coastal Canterbury Streams zone. While this study included only dairy farms, it was chosen over studies that focused on DSL as they used mitigations that were no longer available (DCD), required significant capital expenditure, or were beyond the constraints of Overseer. In addition to this, the DairyNZ Economics Group (2015) study presented mitigations that were clearly structured and broadly relatable to DSL. The author acknowledges that the chosen mitigations were not the only possible way to reduce nitrogen leaching but the most cost-effective option given the modelling constraints (refer to section 4.5.3).

Table 4 outlines the standardised sequential nitrogen loss mitigation protocol that was applied to each farm to achieve the target nitrogen reductions. The protocol aims to achieve a consistent and transparent modelling process between individual farms, by targeting the most cost-effective practices to reduce nitrogen first through de-intensification within the current farm system, in which reductions in farm nitrogen inputs are applied sequentially, followed by the incorporation of a winter stand-off pad which will change the wider system. It is important to note that all mitigation measures were cumulative (i.e. mitigations applied in step 1 are carried through to step 2 and 3). At each step the reduction in feed supply (caused by the mitigation) was balanced by reducing feed demand, as required by Farmax. This was achieved by reducing the stocking rates.

Table 4 : Nitrogen loss mitigation protocol.

Primary mitigation steps	On-farm implementation
1. Reduce autumn nitrogen fertiliser applications to pasture in steps of 25%, then remove	Balance the reduction in feed supply (caused by a reduction in nitrogen fertiliser use) by reducing feed demand (by reducing stocking rates)
2. Reduce unprofitable nitrogen fertiliser applications to pasture	Reduce nitrogen fertiliser that causes large pasture surpluses. Balance the reduction in feed supply (caused by a reduction in nitrogen fertiliser use) by reducing feed demand (by reducing stocking rates). Ensure the pasture covers still exceed the feed demanded
3. Replace imported supplementary feed with high CP content with low CP alternatives	Keep total megajoules of metabolisable energy (MJME) intake per cow from imported supplements constant
4. Sow a cover crop of oats following winter grazing of forage crops if appropriate (i.e. if there is a fallow period between late August and early December)	Cultivate forage crop mid-August, sow oats in late August, apply 40-50 kgN/ha as urea in mid-October, and harvest oats late November as green-chop silage (7.5 tDM/ha yield). Spray and cultivate the oats in early to mid-December. Consistent with the farmer's current cropping rotation, either regrass the paddock or sow a late forage crop (kale) by mid-December (late sown kale yields are expected to be 87% of early sown kale (Edwards et al., 2014) so stock number will need to be decrease if reductions in crop yields result in a feed deficit

5. Replace winter forage crops with high nitrogen leaching risk factors with alterative winter forage crops (starting with crops with the highest risk factor for nitrogen leaching in terms of MJME/kgN) in steps of 25%).	Keep total MJME intake per cow from winter forage crops supplements constant, and increase/decrease the pastoral area if the alternative crop has a higher/lower yield respectively. Harvest the surplus pasture as silage if there is an increase in the pastoral area, and either sell the silage or use it to replace existing imported silage. Consider if this mitigation will impact the crop rotation, and change the hectares of following crops accordingly. If this mitigation involves replacing kale with fodder beet, ensure that the cows are receiving adequate protein from pasture or baleage, and increase baleage consumption if necessary. Ensure the same proportion of the farm is regrassed annually.
6. Reduce winter forage crop areas up to 40% relative to the base farm in steps of 5%.	Balance the reduction in feed supply (caused by a reduction in forage crop) by reducing stocking rates. Ensure the same proportion of the farm is regrassed annually.
7. Incorporate a stand-off pad into the farm system	Restrict the crop grazing regime in winter to eight hours and move the cows to the stand-off pad where they will be fed supplements (increase utilisation rates of supplements). If the cows daily feed allocation also includes pasture, remove the cows from the pasture, harvest the surplus pasture as silage, and feed silage on the stand-off pad (to maintain protein and MJME intake per cow). Effluent from the stand-off pad will be collected and distributed on pasture at times of low leaching risk during the year. Nitrogen fertiliser is reduced in the months that effluent is applied, while keeping the total nitrogen applied to pasture constant (by assuming nitrogen content in effluent is the same as what Overseer assumes).

Firstly, nitrogen fertiliser use was examined; given there were no winter nitrogen fertiliser applications (according to GMP defined by Schedule 24 of the LWRP). Autumn nitrogen fertiliser applications were targeted first due to their higher nitrogen loss risk (Cookson et al., 2001; Di et al., 1999; Ledgard et al., 1988), followed by unprofitable fertiliser contributing to large pasture surpluses. This was done in steps of 25% or removing the whole applications. Following this, high CP content feeds (pasture silage) were replaced by low CP alternatives (maize silage or straw), while maintaining supplementary feeds constant as a proportion of total DM intake. A cover crop of oats was sown if there was a considerable fallow period between late August and early December, following winter grazing of forage crops. Winter forage crop areas with a high-risk factor for nitrogen leaching were then replaced by crops with a lower nitrogen leaching risk factor (as per Overseer) if the alternative crop fitted the farm system, by keeping the total dry matter intake by crops constant. This mitigation required consideration of how alterations in the crop types would impact the crop rotations, the protein supply to livestock, and the total hectares of pasture.

Following this, winter crop areas were reduced by up to 40% relative to the base farm in steps of 5%. If the above mitigations were unable to reduce nitrogen leaching a winter stand-off pad was incorporated into the farm system. For the specific modelling assumptions around this stand-off pad see section 4.5.3.

In addition, a stand-off pad was incorporated into each DSL system without establishing any other mitigations. This mitigation strategy was consistent with on-farm implements made in the last step of the standardised mitigation protocol. The aim of this single mitigation was to also achieve a 22% reduction in nitrogen leaching, therefore the proportion of the stock on the stand-off pad was increased until this target was achieved. The proportion of stock on the stand-off pad was constrained to ensure that all the stock were on the stand-off pad for at least eight weeks. For instance, if the farm wintered 825 cows in April and 700 cows in May, the proportion of stock on the stand-off was adjusted to 84% in April and 100% in May. This was considered the most practical option, given the relatively small benefit and large investment cost of increasing the capacity of the stand-off pad so it could be utilised for a small period.

In all situations, the modelled mitigations did not provide for any productivity gains or improvement in individual farm management capability. This was managed in the modelling process through maintaining consistency in animal live weight profiles and levels of reproductive performance from the baseline, thus constraining the MJME supplied to each animal. There were also constraints on how much imported supplement (as a proportion of total feed offered per cow) could be altered from the base farm system. In addition, stocking rates were not reduced below the point where surplus pasture was produced, which infers land was not required for dairy support and could be retired.

4.5.3 Modelling assumptions

General modelling assumptions

A range of assumptions that were consistent across all farms underpinned the modelling, to ensure the farms were comparable. Firstly, the mitigation strategies that were considered the most cost-effective method to reduce nitrogen loss within the constraints of Overseer. However, it is acknowledged other mitigations, such as diverse pasture and riparian buffer zones, may be a more cost-effective method to reduce nitrogen, however they are not considered within the scope of this research as they cannot be modelled in the current version of Overseer.

The modelling was conducted under the assumption that farmers were operating at a point on a given production possibility frontier which did not shift, therefore the mitigations that would require improved skill and management capability were largely excluded. This assumption was considered important because significant changes in these variables are likely to require farmers to increase their skill level, which would require varying resources (time and money) according to the individual farmer, which are unable to be captured accurately within this modelling. Further, dramatic changes in the above variables are likely to disrupt the existing farm system. The farmer’s skill and management ability are held constant by providing for no livestock productivity gains from the baseline and constraining how much imported supplement (as a proportion of total feed offered per cow) could be altered from the base farm system. Arguably, incorporation of the stand-off pad would require a significant change in the farm system and farmer’s skill (Beukes et al., 2011; Journeaux, 2013), in terms of effluent management, animal welfare, supplementary feeding and labour, however this strategy was only employed in the ‘worst-case’ scenario when the de-intensification strategies were unable to meet the nitrogen targets. These changes were carefully considered when modelling the stand-off pad (see following section).

As aforementioned, the mitigation process was stopped if the farm got to the point where land was retired, as defined as having annual pasture surplus that was either sold or stored indefinitely. It seemed appropriate that modelling was ceased as the economic return from harvesting or selling pasture was expected to be lower than an alternative land use.

Stand-off pad assumptions

Assumptions surrounding the stand-off pad were broadly based on a study conducted by Brown (2014), which investigated the value of incorporating a 400 cow uncovered sealed stand-off pad into a fodder beet wintering system at the Ashley Dene Research Farm. The structure design was based on two mirrored rows of free-stalls with straw bedding for loading, and a separate central feeding lane wide enough for the tractor and silage wagon to drive down. The effluent system was designed to capture and hold all liquid and solid effluent for five months to ensure the effluent could be applied at the correct time. Nitrogen fertiliser was reduced in the months that effluent was applied while keeping the total nitrogen applied to pasture constant (by assuming the nitrogen content in the effluent was the same as what Overseer assumes).

The restricted grazing time was based on a recent study at the Ashley Dene Research Farm which investigated standing cows off forage crops (Jenkinson et al., 2014). The study found that the dry pregnant dairy cows consumed the majority of the crop within six hours of allocation, and that the fodder beet wintering system had the highest utilisation rate (table 5). These findings were slightly lower than a related study (Edwards et al., 2014) which investigated the utilisation of these same crops on the Ashley Dene Farms over 24 hours (table 5). The results from these studies indicate that standing cows off the paddock after eight hours of fodder beet allocation is viable, given the proportion of feed intake within six hours of allocation. Therefore, when using this mitigation strategy, the cows will spend eight hours grazing winter forage crop before being moved onto the stand-off pad where they will be fed supplements. Research has shown the supplementary feed utilisation on a stand-off pad is substantially higher than when fed on a crop paddock (Journeaux, 2013), therefore the utilisation rate of supplementary feed was assumed to be 95% within the stand-off facility which effectively reduced the supplements required relative to the supplements fed on crops or paddocks (which had lower (80%) utilisation rates).

Table 5: Feed utilisation in two trials by Jenkinson et al. (2014) and Edwards et al. (2014) of dry dairy cows grazing kale and fodder beet in winter at the Ashley Dene Research farm.

Treatment	**Diet composition**	**Feed utilisation within six hours** (Jenkinson et al., 2014)	**Feed utilisation over 24 hours** (Edwards et al., 2014)
Early kale	14 kgDM kale, 3 kgDM barley straw	82%	90.6%
Late kale	11 kgDM kale, 5 kgDM green-chop oat silage	76%	87.1%
Fodder beet	8kgDM fodder beet, 6 kgDM grass baleage	90%	99.6%

Overseer nutrient modelling assumptions

To create the Overseer budgets some assumptions had to be made. These were consistent with the Overseer Input Standards. Generally, specific farm input data obtained from the farmer was used, however soil input information for each farm was obtained through utilising the farm's GPS coordinates and information from Landcare Research's S-map database. In addition, the farm's coordinates were put into the Overseer climate station tool to determine long-term climate data and long-term monthly climatic distribution patterns. The soil Olsen P values were set to the Overseer default values, unless the farmer had recent soil test data. Ineffective land area was included in the modelling, and was entered as a native tree and scrub block in Overseer which automatically assigns a nitrogen leaching amount of 3 kgN/ha. This essentially creates a benefit for 'retiring land' from effective areas, such as fencing off and strategically planting critical source areas. The average ineffective area across the case studies equates to 1.8% of the total area modelled, however this was not split evenly with two farms having no ineffective areas and one farm having a 14 hectare ineffective area.

Clarification was sought from the Overseer Support Team as to how to model a forage barley crop. Two of the farmers sowed a spring forage barley and annual ryegrass combination (i.e. forage barley) in August, and harvested the crop as cereal silage in December. Following this cut the barley wilts and is therefore predominantly annual ryegrass. The ryegrass is made into silage and fed *in-situ* to the cows over winter before being cultivated in spring in preparation for winter forage crops. Rather than modelling the crop as a forage barley crop from August to August, the Overseer Support Team recommended to record a forage barley crop sown in August with a cut and carry defoliation in December and sow annual ryegrass in January with the final grazed *in-situ* defoliation occurring in August.

Farmax modelling

A key assumption used in Farmax modelling was the monthly values for pasture growth rates. Although all the farmers monitored their pasture growth rates on their MP, only one farmer monitored the growth rates on their DSL. Therefore, pasture growth rates for three of the DSL farms were derived from the regional database library included with Farmax. During the interviews, the two Farmax pasture curve rates most similar to their DSL farm were shown to these farmers. The farmers were then asked to estimate their pasture growth rates based on these graphs. These estimated growth rates were then calibrated in Farmax after the crop and pasture rotations, nitrogen fertiliser applications, supplementary feed and stock requirements had been defined, so they matched the approximate growth rate of the farm. The response rate to nitrogen fertiliser (kgDM/kgN) and the time for a full response was determined according to the pasture growth rate of the particular month, based on DairyNZ (2012) data.

The majority of the inputs put into Farmax for each farm were obtained from the farmer, including animal performance, feed offered per cow, fertiliser use and crop and pasture rotations. However, standardised feed values were used based on the default values assumed by Farmax, for energy value (MJME/kgDM), and fibre content. Utilisation rates of supplements and kale consumption were 80%, and 90% for fodder beet. Average crop yields are widely variable and dependent on a range of factors (Judson & Edwards, 2008; Matthew et al., 2011), therefore crop yields were determined based on the farmer’s average yields. It was assumed that the same proportion of the farm was regrassed annually when cropping areas were removed from the system following mitigations.

Financial assumptions

The financial analysis was conducted on the DSL block as a standalone business to that of the MP to ensure that the case study farms could be accurately compared. This was relevant to Variation 1, which excludes DSL from the MP. In reality however, the financial budgets for three of the case study farms integrated the DSL block into the larger farming enterprise.

Consequently, there were robust discussions with these farmers during the interview to estimate the independent financial budget for their DSL farm. Because the financial analysis assumed that the DSL was a standalone business, all replacement and winter grazing and supplements imported to the MP were costed and charged to the MP at the market rate. In addition, the labour work was assumed to be done by the DSL staff (rather than MP staff) and was costed accordingly. The assumed standardised grazing payments (J Donkers, personal communication, October 2016) are set on a per week basis and are shown in table 6. These observed grazier payments are expected to remain relatively constant due to the large supply of graziers (as other options for graziers are somewhat limited) and decreased demand from dairy farmers for grazing (the latest milk price downturn has resulted in some farmers wintering their cows on the MP in order to reduce expenses) (J Donkers, personal communication, 2016).

Table 6: Grazing payment for livestock (J Donkers, personal communication, 2016).

Livestock class	**$/head/week**
Calves (weaning to April)	7.50
Yearling heifers (May to April)	12.00
In-calf heifers wintered	20.00
Mixed-age cow winter grazing	22.00

One of the farmers had additional livestock that were not associated with the MP. This farmer purchased bull calves and culled them at as rising three year olds. In addition, carry over cows are purchased and also sold. Default tax values were used to value these livestock purchases and sales, as recommended by Farmax.

Supplementary feed expenses and revenue were based on the average cost in the Canterbury region (J Donkers, personal communication, 2016; H Fraser, personal communication, 2016) and were standardised across all farms (table 7). The cost to produce supplements included fuel and machinery depreciation, and the cost to purchase supplements included transport costs ($28 tDM/ha). It was assumed that it would cost $10 in tractor and bale feeder/silage wagon costs (including depreciation, fuel and repairs) to feed out a tonne of dry matter of supplements (J Donkers, personal communication, 2016). Regrassing costs were calculated using the Farmax default values ($600/hectare).

Table 7: The average cost to purchase, sell and purchase supplements in Canterbury. (J Donkers, personal communication, 2016).

Supplement	Cost to produce ($/tDM)*	Revenue to sell ($/tDM)*	Cost to purchase (including delivery) ($/tDM)*
Pasture silage	$100	$320	$348
Baleage	$135	$350	$378
Hay	$75	$290	$318
Cereal silage	$75	$250	$278
Straw	$65	$170	$195

**These prices are sensitive to feed shortages (droughts), the crop/pasture yield, and the quality of the supplements*

Crop expenses were based on the average direct cost to establish crop in Canterbury (Agricom, 2014; Askin & Askin, 2014; J Donkers, personal communication, 2016; H Fraser, personal communication, 2016) and were also standardised across all farms (table 8). These costs include the cost of spray, cultivation (fuel and machinery depreciation), sowing (drilling and seed), fertiliser and herbicide, according to the requirements of the particular crop. Irrigation is also excluded, as this was accounted for separately in the farms irrigation expenses. Refer to appendix 2 and 3 for a detailed cost analysis of kale and fodder beet crops.

Table 8: The average direct cost to establish crops in Canterbury, excluding irrigation costs.

Crop type	Direct cost to establish ($/ha)
Kale	$1,000
Fodder beet	$2,350
Barley and annual ryegrass	$1,550
Oats and annual ryegrass	$1,550
Forage rape	$900
Ryecorn	$500

Fertiliser expenditure per unit was standardised by using the fertiliser price schedules on the Ravensdown and Ballance website and $13/ha for cartage and spreading (Askin & Askin, 2014). Breeding costs for dairy cows and heifers were excluded, as this was considered a MP expense. Animal health expenses were calculated using the Farmax default. The expenses for wages, irrigation, electricity, vehicles, and repairs and maintenance were based on the budgeted expenditure of each DSL for the 2015-16 season (plus wintering season). These costs were not standardised due to their wide variety according to the farm system context and farm management decisions and preferences. All fixed costs and overhead costs such as administration, rates and insurance were also based on the farm budgets. All farms had a fixed annual cost of $2,500 added to their farm working expenses to represent the ongoing costs of completing an Overseer nutrient budget and farm environmental plan.

The annual operating cost of the winter stand-off pad structure and effluent system were based on commercial quotes to construct a 400 cow uncovered sealed stand-off structure at the Ashley Dene Research farm (Brown, 2014) (table 9). It was assumed that the structure, straw bedding and effluent system would cost $83.55/cow (including depreciation), and the total costs associated with the 400 cow stand-off pad (Brown, 2014) were linearly proportional to the number of cows using the structure, allowing the stand-off costs to be estimated depending on the number of cows wintered on the individual case study farm. It was assumed that heifers required 90% of the area of the structure and effluent system due to their smaller size and therefore the total annual stand-off pad cost per heifer was 90% of the cow cost ($79.20). The interest cost of the stand-off pad (table 9) was analysed separately, as interest is not included in EBIT. In addition to the operating expenses, it was assumed that the annual cost of the stand-off pad and effluent system was $146.27 and $131.64 per cow and heifer respectively. One hundred percent borrowing for the stand-off pad capital investment and 7% interest on borrowings was assumed. It was also assumed that additional labour will be required to shift the cows to and from the stand-off pad. This was added to the farms labour expenses and was estimated at 40 minutes per day on a $21/hour wage rate. Applying effluent to pasture increased the total nitrogen applied, therefore nitrogen fertiliser was reduced accordingly to keep the total nitrogen applied consistent with the base farm. The value of effluent was captured with the reductions in nitrogen fertiliser.

Table 9: Total annual costs associated with a 400 cows stand-off wintering system. Source: Brown (2014)

Cost of stand-off pad (included in EBIT)	
Stand-off wintering pad depreciation @5%	$11,470
Stand-off wintering pad repairs and maintenance	$5,000
Effluent storage @5% depreciation	$6,450
Straw bedding	$9,000
Straw removal and spreading	$1,500
Total annual operating cost @400 cows	**$33,420**
Total annual operating cost/cow	**$83.55**
Total annual operating cost/heifer	**$79.20**
Additional interest cost of stand-off pad (after EBIT)	**$25,088**
Stand-off wintering pad @7% interest on capital cost	$16,058
Effluent storage @7% interest on capital cost	$9,030
Total annual cost of @ 400 cows	**$58,508**
Total annual cost/cow	**$146.27**
Total annual cost/heifer	**$131.64**

The above operating profit and expenses were imported into Farmax. The total operating costs and expenses of all key marginal inputs were varied appropriately according to the individual mitigation strategy. The contract grazing payment, and freight and animal health expenses were set on a per cow basis. Labour and vehicle expenses were also set on a per cow basis, as the farmers noted that the majority of labour time consisted of moving cows. Total fertiliser expenses were dependent on the volume of fertiliser, while total feed and the associated machinery expenses were driven by the amount of feed made, sold or purchased. Likewise, total forage crop expenses were adjusted according to the hectares of each crop established.

Chapter 5

Results

5.1 Introduction

This chapter presents the case study profiles of the four farmers who participated in this research. The farmers were located in the Selwyn Waihora catchment, and owned a MP and DSL. Each farmer has been assigned a letter for confidentiality reasons.

Section 5.2 to 5.5 details the case study profiles, which will provide an overview of each farmer's total dairying operation, as well as the farmer's reasoning for purchasing the DSL block and the management operations of their existing dairy support system. The environmental performance of the current system is determined using Overseer (version 6.2.3). Following this, the environmental, physical and financial implications of a 22% reduction in nitrogen losses is analysed by using Overseer and Farmax modelling tools simultaneously. Section 5.6 summarises the findings from all the case studies farms and section 5.7 details the abatement cost of reducing nitrogen loss on each farm.

5.2 Case Study A

5.2.1 Overview

Farmer A's total dairying operation encompasses two irrigated dairy farms (334 total effective hectares), across which 1,170 cows were milked in the 2015-16 season (3.5 cows per hectare). The dairying operation also includes a small leased DSL block adjacent to one of the dairy farms, and 106.3 effective hectares of owned DSL located a small distance from the MPs. The focus of this case study is placed on the later DSL block, which consists of 80% of the enterprises total support. This DSL is hereafter referred to as the 'main DSL block'.

Fodder beet has been recently grown on both MPs (19 hectares total), on which all the cows are milked and transitioned on in May and almost half the cows are wintered. Fodder beet was incorporated into the MPs for a number of reasons; to eliminate the risk and *"hassle"* associated with third party graziers, save on silage and cows transport costs, utilise labour during winter, achieve better cow condition and contribute to the pasture renewal programme. During the wintering period, the remaining half of the herds cows are split between the two DSL blocks and are fed kale or fodder beet crops. The main DSL block is also used to supply baleage to both MPs and raise all the heifer replacements (9 month old calves to heavily pregnant heifers), while the other DSL block is used to graze all replacement calves (weaners to 9 months old). DSL has allowed the overall dairy system to be self-sufficient with its grazing, as well as partly self-sufficient with its supplements (approximately 20% of the MPs supplements consists of baleage imported from the DSL). Farmer A was "*really happy with how the (overall dairying) system worked"* and perceived it is "*an integrated system".*

5.2.2 Reasoning for purchase

Farmer A purchased the main DSL block in 2014 from a mixed sheep, beef and cropping farmer. The primary reason behind Farmer A's decision to purchase this DSL block was to gain greater control over the feed supplies necessary to support the MPs; to secure the grazing of young stock, winter a portion (13%) of the herd, and provide feed to be transferred to the MPs. Prior to the purchase, the farmer had substandard experiences (growth targets not met and price volatility) with third party graziers. Farmer A notes that although it is *"probably cheaper to use a grazier at current prices"* and the DSL *"has not saved any money (due to debt repayments)", "lots of volatility is taken away by… (grazing replacements and wintering cows) yourself"* and *"we have control".* Overall, the DSL purchase was perceived to be *"just another way of risk management".* Therefore, it is evident that the underlying reasons for the DSL purchase related to risk management and control, as opposed to optimising profitability.

The close proximity of this DSL block to nearby townships also offers potential for long-term housing investments, however this is considered a secondary reason for purchase. In addition, the DSL has *"better soils than the MPs",* which contributed to the purchase. Farmer A notes that nitrogen regulations (under Variation 1) restricts the DSL being converted into a MP in the future, and bull beef enterprises and potato cropping would result in less baleage production and potentially higher nitrogen leaching; therefore, DSL is currently seen as the lands best use.

5.2.3 Dairy support operation

The main DSL block is 106.3 effective hectares (110 total hectares) and is irrigated with centre pivot (54.3 hectares) and rotorainer irrigation (52 hectares) from September to April. There are three main soil types on the property, including Templeton silt loam, Barrhill silt loam and two siblings of Eyre silt loam. The farm supports the grazing needs of all the heifer replacements from both MPs (280 heifers), which arrive at the property in May each year and remain there until the end of June in their second winter. An additional 150 late calving cows are also on the farm from June, and are staggered back to the MP just before calving (79 average grazing days/cow).

A cropping rotation of pasture – fodder beet – barley and annual ryegrass (forage barley) – kale – barley and annual ryegrass – kale or fodder beet is grown on light soils under the areas irrigated by the rotorainer. Last year, 22.1 hectares of kale and 6.9 hectares of fodder beet were grown, which formed the basis of the wintering system. In addition, 18 hectares of forage barley was grown, which was harvested as cereal silage in November before being grazed as annual ryegrass by the stock. A total of 920 bales of baleage and 360 bales of cereal silage were produced and retained on the DSL, and an additional 290 baleage bales were sent to the MPs. Straw (20 tDM) was also imported. The majority of these supplements were fed during the wintering period. Nitrogen fertiliser is applied to the pasture area at approximately 160 kgN/ha/year. Based on measured crop yields, baleage harvested and the stock grazed, on average, 13,500 kgDM/ha/year is grown across the DSL block.

5.2.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 54.3 kgN/ha over the total farm area. Kale and fodder beet crops occupy 27% of the total effective area and leach 86% of the farms total nitrogen.

Table 10: Summary of Overseer blocks and nitrogen leaching on Farm A

Block	Hectares	Nitrogen leaching (kgN/ha/year)
Pasture: RR: Templeton	4.6	14.8
Pasture: RR: Barrhill 5	2.5	13.6
Pasture: Pivot: Templeton	6.9	9.3
Pasture: Pivot: Barrhill 5	10.9	9.0
Pasture: Pivot: Eyre	28.5	12.1
Pasture: Pivot: v light Eyre	5.9	9.1
Barley+grass: RR: Templeton	2.0	6.5
Barley+grass: RR: Eyre	11.4	7.1
Barley+grass: RR: Barrhill 5	2.0	6.5
Barley+grass: RR: Barrhill 6	2.6	6.2
Kale: RR: Barrhill 5	9.0	130.2
Kale: RR: Barrhill 6	4.4	285.0
Kale: RR: Eyre	8.7	204.9
Fodder beet: RR: Barrhill 6	6.9	131.9
Average nitrogen leached (kgN/ha/year)		**54.3**

The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 22% from the base model:

1. Removal of fertiliser applied to the pastoral area in May (32 kgN/ha).

2. Removal of all (280) rising one year olds grazing in May to recover from pasture deficit.

3. A 50% (11.1 hectare) reduction in the kale cropping area and a 58% (4 hectare) increase in the fodder beet area. This resulted a 12% (7.1 hectare) increase in the pasture area.

4. An increase (42 tDM) in silage production in response to the pasture surplus. This silage was used to meet the target feed ratio (fodder beet 60: silage 40) for cows grazing on the increased area of fodder beet.

This resulted in a 26.8% reduction in nitrogen leaching from the base, while only requiring minor reductions in stock numbers. The above changes resulted in a reduction in EBIT of 36.7%. Reductions in contract grazier revenue and increases in silage making expenses contributed to a large proportion of this reduction (50% and 21% respectively). Revenue from contract grazing decreased by 5.7% and silage production costs increased by 14.5%.

Forage crop and nitrogen fertiliser expenses decreased by 2.6% and 13.6% respectively. It is worth noting that this farm had a low EBIT to start with, therefore the absolute reduction is relatively small in absolute terms. However, this also meant that the high relative change (26.8% reduction) could leave the farm with very little EBIT left to pay interest, tax, capital improvements and repay debt and they are unlikely to be able to meet these financial obligations.

The stand-off pad mitigation resulted in the following changes:

- 100% of stock utilising the stand-off pad from May to August. The stock were grazed only on crop during this time, therefore the pasture blocks were unchanged.
- All supplements fed from May to August were fed on the stand-off pad, with a higher utilisation rate, therefore 20% less supplements were fed out during this period and 49 tDM of baleage and 8.2 tDM of cereal silage was sold.
- 6.3% reduction in nitrogen fertiliser use (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in an 8.4% reduction in nitrogen leaching and a 71.3% reduction in EBIT from the base. Total revenue increased by 2.5%, due to the increased sales of supplementary feed. Expenses were increased by 51%, largely due to the significant cost ($44,352) of the stand-off pad. Nitrogen fertiliser expenses decreased by 9.8% and wages increased by 9.8%. When the interest cost was included in addition to the operating expenses of the stand-off pad ($73,718 total), EBIT was reduced by 133%. This interest cost made the farm financially unviable.

5.3 Case Study B

5.3.1 Overview

Farmer B owns two MPs, milking a total of 1,530 cows on 387 effective hectares (4 cows per hectare). The farmer is a strong advocator of the resilience of pasture based systems which forms the basis of both his MPs. However, last season fodder beet was sown on the MPs and fed during late lactation in response to the low milk price.

The dairying operation also includes 160 effective hectares of DSL, located in close proximity to one of the MPs. The DSL is used to raise replacement heifers, and supply supplementary feed to the MPs. This block is usually unable to be wintered on due to its heavy, poorly drained soils, therefore the rising two year olds and cows are wintered *in-situ* on forage crops purchased as standing from a neighbouring farmer. Farmer B places great emphasis on maintaining optimal control of the feed supplies necessary to support the total dairying enterprise, which has been achieved through the DSL and wintering on standing crops. Due to this control, Farmer B is content that his total dairying operation is *"a very good system".*

5.3.2 Reasoning for purchase

Farmer B purchased 80 hectares of DSL in 2007 for grazing replacement calves. The block had been previously run as a beef fattening block. In 2013, another 80 hectare block of cropping land adjacent to the existing DSL block came up for sale and was purchased by Farmer B for replacement heifer grazing. The main driver behind these two purchases was attaining optimal control over the whole dairying operation. Farmer B describes the inability of third party graziers to grow heifers as a *"wicked problem experienced throughout the country". "they were coming back at 400-450 kgs…all I want to see is my stock fed well…I don't think they (the graziers) realise they have our next year's production in the palm of their hand".* It was therefore through frustration that the DSL was purchased, as it provided a means of control over the future productivity of the MPs. *"It was a no-brainer to buy the other block when it came up, it meant I could …graze my…heifers. You cannot afford to give someone control of your stock, simple as that".*

Farmer B believes that the DSL is beneficial to the overall dairying enterprise. Since the purchase, the condition of in-calf heifers returning to the MPs has improved significantly. "*Previously they were coming back at 400 to 450 (kgs), now they are coming back at almost 500 (kgs)".* In addition, herd tests have indicated that milk production has increased *"On average, each heifer's milk production is now 80% of the mixed age cows rather than 75%, just from the heifers being grown out properly"*. Flexibility when drying cows off was considered a secondary benefit of the DSL purchase.

5.3.3 Dairy support operation

Farm B is a 160 (effective) hectare DSL block and is fully irrigated with rotorainer irrigation from October to March. A large proportion (80%) of the property is artificially drained, as its soils are predominantly poorly drained. The farm is used exclusively for grazing all the replacement heifers from both MPs. Heifer calves arrive on the DSL block in December as weaners and are taken through to 21 months of age before returning to the MP at the end of May. The rising one year old heifers are typically wintered off the DSL to avoid soil pugging, however dry winter conditions have allowed the calves to be wintered in the last two years.

Last year, 6 hectares of fodder beet and 8 hectares of rape were grown primarily to winter the rising one year olds. In addition, 15 hectares of ryecorn was grown for heifer grazing during spring. Supplementary feed production included 250 hay bales, 200 baleage bales and 530 tDM of pasture silage, of which 100 baleage bales were retained and the rest was sent back to the MPs. No supplements were imported into the farm system. Nitrogen fertiliser was applied to the pasture area at approximately 160 kgN/ha/year, from August to March. Farmer B places a strong emphasis on high performing young grass to achieve the target growth rates of his replacement stock. Half the DSL was sown into new pasture two years ago when it was purchased, while just over 10% of the remaining DSL is regrassed each year.

5.3.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 18.4 kgN/ha over the total farm area. Crops represented 18% of the total farm area and were responsible for 57% of the farms total nitrogen losses. Fodder beet leached significantly higher concentrations of nitrogen relative to the other blocks, and was responsible for 40% of the farms total nitrogen leaching despite occupying only 4% of the farms area.

Table 11: Summary of Overseer blocks and nitrogen leaching on Farm B

Block	Hectares	Nitrogen leaching (kgN/ha/year)
Pasture: RR: Ayre 1	87.0	6.9
Pasture: RR: Ayre 3	34.0	7.1
Pasture: RR: Darn1	16.0	20.0
Pasture: RR: Yami18	23.0	8.3
Fodder beet	6.0*	100.7
Rape	8.0*	58.3
Ryecorn	15.0*	48.2
Average nitrogen leached (kgN/ha/year)		**18.4**

**These areas rotate through the Ayre pasture blocks, therefore are not calculated in the total hectares*

Under Variation 1, nitrogen leaching losses of 15 kgN/ha/year and under are a permitted activity. Therefore, this farm requires a 18.5% reduction in nitrogen leaching to meet this target, rather than a 22% reduction. The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 18.5%:

1. Removal of fertiliser applications to pasture in March (25 kgN/ha).

2. A 9% reduction in rising two year olds (35) from 1st April until the 31st May to recover from pasture deficit.

3. Rape leached the most nitrogen on the basis on MJME/kg N (rape: 1235 MJME/kgN; ryecorn: 2075 MJME/kgN; fodder beet: 2790 MJME/kgN). Therefore, the rape crop (8 hectares) was replaced with kale (4.4 hectares) (keeping MJME/cow constant). Kale was chosen as a substitute as it is a similar crop in terms of yield and grazing period, and it leached lower concentrations of nitrogen. The pasture area was increased by 3.6 hectares (2.7%).

4. A 10% (0.6 hectare) reduction in the fodder beet cropping area.

5. A 2.5% reduction in rising two year olds (10) from the 16th February to the 31st March.

6. A 3.5% reduction in rising one year olds (15) from the 16th May to the 1st August.

The above changes reduced nitrogen by 18.4%, resulting in a 2.4% reduction in stocking units per hectare (from 16.5 to 16.1) and a 0.4% increase in EBIT. Reductions in contract grazing revenue, and nitrogen fertiliser and forage cropping expenses contributed to a large proportion (47%, 22% and 29% respectively) of this relatively small increase. Total revenue was reduced by 1.6%, largely due to the reduction (2.7%) in contract grazing revenue. Total expenses were reduced by 4.9%; nitrogen fertiliser and forage cropping expenses decreased by 9.8 and 14.6% respectively. The reduction in both total revenue and expenses offset each other, resulting in little change in EBIT.

The stand-off pad mitigation resulted in the following changes:

- 85% of stock utilised the stand-off pad in April and 100% of stock utilised the stand-off pad from May to July. Prior to this mitigation the stock were grazed on crop and pasture *in-situ*. This mitigation removed all stock from the pasture from May to August.
- A 23.4% (123 tDM) reduction in pasture silage sold off farm, as silage was fed to the stock on the stand-off pad (4.2 tDM/day) to replace the pasture they no longer consumed *in-situ.*
- 20% (7 tDM) reduction in baleage consumption, as utilisation rates of baleage fed on the stand-off pad were increased by 20%. This baleage was sold off farm.
- 3% reduction in nitrogen fertiliser (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in a 12.2% reduction in nitrogen leaching and a 38.5% reduction in EBIT from the base. Total revenue decreased by 6.6% due to the decrease in revenue from supplement feed sales. Expenses increased by 17.2%, largely due to the significant cost of the stand-off pad ($55,282). Wages increased by 14.3% and nitrogen fertiliser expense decreased by 4.6%. The farm experienced a 54% reduction in EBIT when the cost of interest was added to the stand-off pad ($91,885).

5.4 Case Study C

5.4.1 Overview

Farmer C manages a large scale dairying operation owned by his family business. The enterprise includes six MPs (2,420 total hectares) milking a total of 8,750 cows and three DSL blocks which are located approximately three kilometres from four of the MPs. The first DSL block (70 hectares) was recently purchased for calf grazing. The second block (72 hectares) is used for wintering cows and calf grazing, and the third block (65 hectares) is used for wintering cows and producing silage for the MPs. The focus of this analysis from hereafter is on the third DSL block, which provides the largest proportion of support to the MP relative to the other DSL blocks. Farmer C uses third party support services for some grazing and supplementary feed, however the DSL provides greater control. In addition, 30 hectares of fodder beet is grown on the MPs for wintering cows. Farmer C describes his dairying system as having *"good balance"*, due to his successful relationship with his third party grazier and his low exposure to the market in terms of feed supplies.

5.4.2 Reasoning for purchase

Farmer C purchased the DSL in 2002 from a dryland sheep farmer. Attaining more control over winter grazing and supplementary feed, as well as the close proximity to the MPs were the primary reasons for purchase. Prior to the purchase, all the cows were wintered on the MP. Farmer C notes that the current system is much more *"cost-effectiv*e", in which the DSL produces a larger amount of dry matter per hectare. The farmer is aware that if all the cows were wintered off using a third party grazier, the business would be *"heavily exposed to the market".* Secondary reasons for purchase include the benefit of land appreciation, the flexibility of sending cows on and off, and the opportunity to diversify the business (cash cropping).

5.4.3 Dairy support operation

Farm C is 63.1 effective hectares and is fully irrigated with two lateral irrigator runs from October to late March. Soils on the property are predominantly well drained, shallow stony loams. Farm D is used for wintering 1,350 dairy cows which arrive from the 1st June and are staggered leaving just before calving (58 average grazing days/cow).

In the last three years the farm has implemented an intensive, systematic cropping rotation of barley and annual ryegrass (forage barley) – fodder beet – barley and annual ryegrass – kale. This year, 13.7 hectares of kale and 15.4 hectares of fodder beet were grown for wintering cows. In addition, 30.9 hectares of barley and annual ryegrass was grown. This was harvested as cereal silage in December and sent back to the MPs for cow transitioning prior to calving. Another two cuts of silage were taken in late January and March for the MPs, before the pasture was shut up for *in-situ* winter grazing. Straw (115 tDM) was purchased to supplement the cows on the winter forage crops. Next year, Farmer C will grow peas as an additional income stream between the grazing of forage crops and sowing of barley and annual ryegrass. Timing, planning and attention to detail were key features of this case study.

5.4.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 38.7 kgN/ha over the total farm area. The fodder beet crop leached almost twice as much nitrogen per hectare relative to the other crops. Nitrogen leaching from the barley and annual ryegrass crop increased over four-fold if the crop was previously sown in fodder beet rather than kale.

Table 12: Summary of Overseer blocks and nitrogen leaching on Farm C

Block	**Hectares**	**Nitrogen leaching (kgN/ha/year)**
Kale	13.7	23.1
Fodder beet	15.4	80.5
Fodder beet – Barley and annual ryegrass	16.1	44.3
Kale – Barley and annual ryegrass	14.8	8.3
Pasture	3.1	14.2
Average nitrogen leached (kgN/ha/year)		**38.7**

The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 22%:

1. Fodder beet leached the most nitrogen on the basis of MJME/kgN (fodder beet: 4212 MJME/kgN; kale: 6856 MJME/kgN). Therefore, the fodder beet crop was reduced in steps of 5% and replaced with kale crop. In the end, the fodder beet crop

was reduced by 45% (6.9 hectares) and kale crop was increased by 109% (14.9 hectares) (keeping MJME/cow constant).

2. As a result, 37.1 hectares of the rotation area was in forage crop, while only 22.9 was in barley and annual ryegrass. This was considered unsustainable, as the rotation needs to be 50:50 crop and barley annual ryegrass. Therefore, the kale crop was reduced by 7.1 hectares so the kale and fodder beet areas totalled 30 hectares.

3. Cow numbers were reduced by 13.3% (180 cows), as a result of the reduction in kale crop.

The above changes reduced nitrogen by 22.5%, resulting in a 13.3% reduction in cow numbers and a 12.2% decrease in EBIT. Reductions in contract grazing and supplementary feed sales revenue contributed to 70% and 9.6% of this reduction respectively. Total revenue decreased by 9.3%; revenue from contract grazing and supplementary feed was reduced by 13.4% and 2.9% respectively. Total expenses decreased by 5.9%; forage cropping expenses were reduced by 10%. The decrease in total expenses slightly offset the larger reduction in total revenue.

The stand-off pad mitigation resulted in the following changes:

- All the cows utilised the stand-off pad when they were on the farm (June to August). Prior to this mitigation the stock grazed crop and annual ryegrass *in-situ*. This mitigation removed all the cows from the pasture.

- Pasture no longer consumed *in-situ* (139 t DM) was harvested as silage and 80% (112 tDM) was fed to the cows on the stand-off pad (20% reduction in pasture consumption due to increased utilisation rates), while the remaining 20% was sold off-farm.

- All straw was fed on the stand-off pad. Straw consumption (and purchases) decreased by 20 % (23 tDM), as utilisation rates of straw fed on the stand-off pad increased by 20%.

- 8.5% reduction in nitrogen fertiliser to crop (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in a 14.9 % reduction in nitrogen leaching and a 55.7% reduction in EBIT from the base. Total revenue increased by 2.3% due to the additional supplementary feed sales. Expenses increase by 70.4% largely due to the significant cost of the stand-off pad ($115,493). Wages and conservation crop expenses increased by 20.2% and 30.1% respectively. The farm experienced a 116% reduction in EBIT when the cost of interest was added to the stand-off pad ($197,465).

5.5 Case Study D

5.5.1 Overview

Farmer D's overall farming enterprise includes four MPs (1,020 effective hectares) milking a total of 3,580 cows and two DSL blocks. The first DSL block (375 effective hectares) is located approximately 20 kilometres from the MPs and grazes all the replacement stock for the enterprise. The second block was purchased last year for the purposes of wintering all the enterprises cows and producing supplementary feed. The focus of this analysis is on the older, well established DSL block (375 effective hectares).

This farming operation places a great emphasis on having high levels of transparency between each individual enterprise. To attain this, each of the farms are treated as a standalone enterprise. All movements of feeds between the different farms, including labour transfers, as well as grazing, is fully priced and charged at the market rates. Farmer D is therefore able to accurately assess and evaluate the financial performance achieved by each farm, and ascertain how each contributes to the company as a whole.

5.5.2 Reasoning for purchase

Farmer D purchased this DSL in 2011 from a sheep and beef farmer. The primary reason for the purchase was to attain optimal control of the dairy systems replacement stock. Previously, Farmer D utilised third party graziers however purchasing a DSL block meant the farmer *"could only blame himself"* when it came to effectively achieving heifer growth rate targets. Overall the DSL provides better control, flexibility and management of growth rates. Farmer D notes that it would be very difficult to find a third party grazier who could provide grazing for over 3,300 heifers, and a benefit of the current system is having all the replacement stock in one location which is handy to the MPs. A secondary benefit of the DSL purchase is land appreciation. Farmer D notes the potential for the land to be used for housing developments or dairy farm conversion in the future. The future of the DSL will determined by a review in the near future.

5.5.3 Dairy support operation

Farm D is 375 effective hectares. The farm is fully irrigated by centre pivot irrigation from September to late April, using soil moisture tape monitoring for scheduling. Farm D is used exclusively for grazing all the replacement heifers for the dairying enterprise. Heifer calves (1,600) arrive on the farm as weaners in mid-December and are taken through to 22 months of age before leaving the DSL at the end of April as in-calf heifers. A small proportion (290) remain and are wintered through to the end of May before being sent back to the MPs. In addition, 70 bull calves are purchased in January and are taken through to November in the following year before being sent to the MPs for two months of mating and later sent to the works as rising three year olds. These bulls are used to mate the heifers on the DSL as rising two year olds. There is no feed interaction between this DSL block and the MPs.

A total of 10% of the effective farm area is used for winter forage cropping. Last year, 26 hectares of fodder beet and 10.5 hectares of kale was grown for heifer wintering purposes. Baleage is made during periods of pasture surplus – last year 230 tDM of baleage was produced and retained on the farm. The farm also imports 150 tDM of pasture silage. The majority of these supplements are fed in winter as a component of the fodder beet diet, however some supplements are fed in spring and autumn. Nitrogen fertiliser is applied as urea to pasture every month from August to March, totalling approximately 200 kg N/ha/year. Approximately 18% of the effective area is regrassed each year (30 hectares perennial ryegrass, 39.5 hectares annual ryegrass). Farmer D places a strong emphasis on achieving the target growth rates set for the replacement stock. A sophisticated weighing system is used regularly to weigh all stock and feed them accordingly. *"What drives the farm is (livestock) weight".*

5.5.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 37.4 kgN/ha over the total farm area. Fodder beet leached significantly higher concentrations of nitrogen relative to the pasture and kale blocks, and was responsible for 37% of the farms total nitrogen leaching despite occupying only 7% of the farms area.

Table 13: Summary of Overseer blocks and nitrogen leaching on Farm D

Block	Hectares	Nitrogen leaching (kgN/ha/year)
Pasture	349.0	22.7
Kale	10.5*	116.0
Fodder beet	26.0	206.8
Average nitrogen leached (kgN/ha/year)		**37.4**

**This area rotates through the pasture block, therefore is not calculated in the total hectares*

The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 22%:

1. Removal of fertiliser applications in March (25 kgN/ha).

2. A 1.6% (25 cow) reduction in rising two year olds from the 16th February to the 30th April to recover from the resultant pasture deficit.

3. Establish an oat cover crop in August following half of the kale crop (crop grazed prior to August) and all the fodder beet crop (23.5 hectares). The cover crop is harvested in late November as silage (7.5 tDM/ha) and perennial ryegrass is sown (consistent with the farms current rotation). All oats silage is sold off the farm.

4. Kale leached the most nitrogen relative to fodder beet on the basis of MJME/kgN (kale: 991 MJME/kgN; fodder beet: 1,237 MJME/kgN). Therefore, kale was reduced and replaced by fodder beet in steps and eventually was replaced by fodder beet (4.9 hectare increase in fodder beet) (keeping MJME/cow constant). The pasture area increased by 5.6 hectares as a result.

5. A 15% (4.6 hectare) reduction in fodder beet crop.

6. A further 3.3% (50 cow) reduction in rising two year olds grazing olds from the 16th February to the 30th April and removal of all (290) rising two year olds grazing during May as a result of reduced fodder beet crop.

The above changes achieved a 22% reduction in nitrogen leaching, resulting in a 2.7% decrease in stock units and a 3.5% increase in EBIT. Total revenue was reduced by 1.1%. Contract grazing revenue was reduced by 1.1% and there was an introduction of feeds cereal silage sales which increased the sold supplementary feed revenue by $49,313. Total expenses were reduced by 0.3%. Forage cropping expenses increased by 43.3% and nitrogen fertiliser expenses reduced by 17%. If the cover crop was removed from the mitigation process, nitrogen leaching was reduced by 21% and EBIT was increased by 1.7%, therefore it was more cost-effective to use this cover crop as a mitigation.

The stand-off pad mitigation resulted in the following changes:

- Stock utilised the stand-off pad from April to August when they were grazing winter forage crops. The proportion of stock on the stand-off pad differed (April: 49%; May: 78%; June: 92%; July: 92%; August; 92%), as this was considered the most practical option given the relatively small benefit of increasing the stand-off pad capacity for a five week period in April and May when there were large numbers of stock. Bulls were also excluded from the stand-off pad.

- Previously the stock consumed 3.7 kgDM/day of pasture *in-situ*, therefore 879 tDM of pasture silage was harvested and fed to the stock on the stand-off pad to keep MJME and protein intake constant (assuming 20% higher utilisation rate).

- 50% (75 tDM) of the purchased pasture silage was fed on the stand-off pad. Due to higher utilisation rates, 20% (15 tDM) of this was not required and was therefore not purchased.

- 5.6% reduction in nitrogen fertiliser (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in a 24.5% reduction in nitrogen leaching and reduced EBIT by 47%. Total expenses increased by 25.1%, due to the large increase in silage production and the significant cost of the stand-off pad ($126,720). The farm experienced a 65.7% reduction in EBIT when the cost of interest was added to the stand-off pad ($210,624).

5.6 Summary of case studies

5.6.1 Base farm information

Category	**Case Study**			
	A	**B**	**C**	**D**
Dairy (MP)				
Number of MPs	2	2	6	4
Total effective hectares	334	387	2,420	1020
Total cows (peak milking)	1,170	1,530	8,750	3,600
Average stocking rate (cows/ha)	3.5	4.0	3.6	3.5
Average production (kgMS/cow)	1,627	1,677	1,423	1,569
Average production (kgMS/ha)	463	424	394	444
Dairy support land (DSL)				
Effective hectares	106.3	160	63.1	375
Ineffective hectares	3.7	0	0	14
Total hectares	110	160	63.1	389
Topography	Flat	Flat	Flat	Flat
Climate	593 mm/year rainfall 11.9 °C mean annual temperature 885 annual PET (mm)	609 mm/year rainfall 11.8°C mean annual temperature 910 annual PET (mm)	575mm/year rainfall 11.9°C mean annual temperature 897 annual PET (mm)	682 mm/year rainfall 11.8°C mean annual temperature 927 annual PET (mm)
Soil type and drainage	13% Templeton silt loam, well drained; 36% Barrhill sandy loam, well drained; 52% Eyre stony silt loam, well drained	76% Ayre deep clay, poorly drained; 10% Darnley silt loam, moderately, well drained; 14% Waimairi peat over silty loam, very poorly drained 80% artificially drained	100% Rakaia stony sandy loam, well drained	100% Lismore silt loam, well drained

Category	Case Study A	Category B	Case Study C	Category D
Year of purchase	2014	2007	2002	2011
Reasons of purchase (*=primary reason)	Greater control* Risk management Long-term investment-housing Good cropping soils	Attain optimal control* Substandard third party grazier experiences Flexibility	Greater control* Close proximity to MP Risk management Opportunity to diversify	Control, self-sufficiency* Close proximity to MP Risk management Investment opportunity – housing development/ dairy farm conversion Flexibility Land appreciation
DSL uses	Heifer grazing Winter grazing (cows) Baleage for MP	Heifer grazing Supplements for MP	Winter grazing (cows) Silage for MP	Heifer grazing Bull enterprise
Stock type and numbers	280 heifers (9 to 22 months) 150 cows wintered (79 average grazing days/cow)	430 heifers (3 to 21 months, only 210 are wintered as rising one year olds)	1350 cows wintered (58 average grazing days/cow)	1,600 heifers (4 to 22 months) 290 heifer yearlings wintered in May 70 bull calves (5 to 27 months)
Stocking units (SU/ha)[9]	18.4	16.5	14.9	26.8
Irrigation (% of effective area)	49% Briggs rotorainer, 51% centre pivot	100% Briggs rotorainer	100% linear pivot	100% centre pivot (soil moisture tapes)
Crops grown (ha; yield (tDM/ha)	Kale- 21.2; 10 Fodder beet- 6.9; 25 Forage barley- 18 ha	Rape- 8; 4 Fodder beet- 6; 20 Ryecorn- 15; 10	Kale- 13.7; 15.5 Fodder beet- 15.4; 30 Forage barley- 30.9 ha	Kale- 10.5; 10 Fodder beet- 26; 20
Winter crop (% effective area)	27	9	46	10
All crop (% effective area)	44	18	95	10

[9] Stocking units is defined as an animal with an intake of 6,000 MJME intake per year

Category	Case Study	Category	Case Study	Category
	A	**B**	**C**	**D**
Nitrogen applied to pasture (kg/ha/year)	160	160	0	200
Supplements harvested (tDM)	275 baleage (32% retained, 68% sent to MP) 151 cereal silage (100% retained)	88 hay (100% sent to MP) 525 silage (100% sent to MP) 70 baleage (50% retained, 50% sent to MP)	386 cereal silage (100% sent to MP) 185 pasture silage (100% sent to MP)	230 baleage (100% retained)
Imported feed (tDM/ha)	20 straw	0	115 straw	150 silage
Nitrogen conversion efficiency (pastoral) (%)	54	55	50	24
Nitrogen leaching (kg N/ha/year)	54.3	18.4	38.7	37.4
Nitrogen coming from all crops (%)	89	57	98	45
Nitrogen coming from winter forage crops (%)	86	34	64	45
Total operating revenue breakdown	77% contract grazing 23% supplement sales	63% contract grazing 37% supplement sales	61% contract grazing 39% supplement sales	97% contract grazing 3% bull sales
Total operating expenses breakdown (top 5 expenses only)	24% forage crops 17% wages 15% conservation feed 10% nitrogen fertiliser 8% irrigation	21% irrigation 19% conservation feed 17% nitrogen fertiliser 9% forage crops 6% regrassing	54% forage crops 23% conservation feed 7% irrigation 5% wages 1% vehicle	21% nitrogen fertiliser 17% irrigation 17% wages 10% conservation feed 8% forage crops

5.6.2 Mitigation results summary

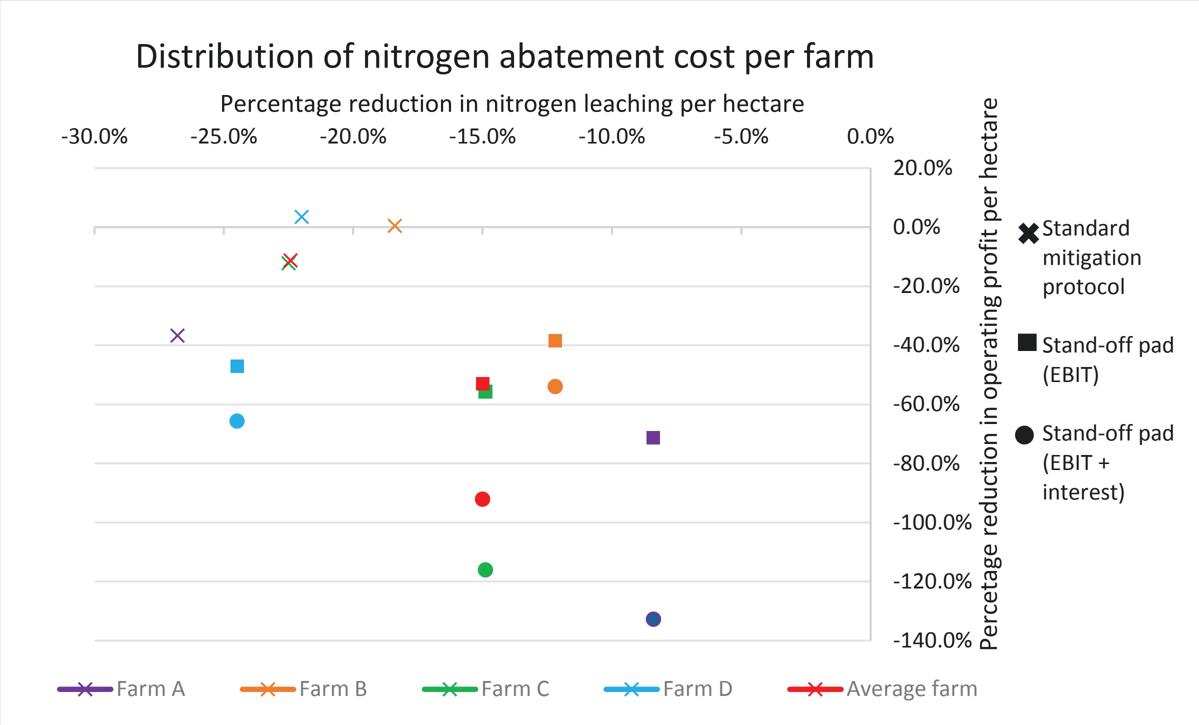

Figure 11: Distribution of nitrogen abatement cost per farm.

Table 14: The impact of the standarised nitrogen mitigation protocol on operating profit.

	Change in nitrogen leaching (%)	**Change in EBIT (%)**
Farm A	-26.8%	-36.7%
Farm B	-18.4%	0.4%
Farm C	-22.5%	-12.2%
Farm D	-22.0%	3.5%
Average	-22.4%	-11.3%

Table 15: The impact of the standoff pad on operating profit, and operating profit and interest.

	Change in nitrogen leaching (%)	**Change in EBIT (%)**	**Change in EBIT + interest (%)**
Farm A	-8.4%	-71.3%	-132.7%
Farm B	-12.2%	-38.5%	-54.0%
Farm C	-14.9%	-55.7%	-116.0%
Farm D	-24.5%	-47.0%	-65.7%
Average	-15.0%	-53.1%	-92.1%

Chapter 6

Discussion

6.1 Introduction

The objective of this research project was to understand the implications of nitrogen regulation on the performance of dairy support farms in the Selwyn Waihora catchment in Canterbury. The literature review in Chapter 3 identified a gap in the knowledge surrounding DSL in Canterbury, particularly in regard to the nitrogen leaching rates achieved through different DSL management operations and the implications of nitrogen constraints on DSL. This led to the research questions:

- What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?
- What are the current management practices used on DSL in Selwyn Waihora?
- How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?
- How will Variation 1 impact the future physical, environmental and economic performance of DSL?
- How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

The purpose of this chapter is to discuss the research findings in relation to the five research questions. Comparisons of the findings with literature were made where appropriate. Each research question has a concluding summary.

6.2 What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?

All study participants emphasised that achieving greater control over their overall dairy enterprise was the strongest motivator behind their DSL purchase. These farmers recognised DSL as being a means to gain direct control of the feed supply and the condition of livestock in the overall dairy system by wintering cows, growing supplementary feed and raising young stock. Throughout the interviews it became evident that the farmers were prepared to sacrifice profitability in order to attain this control. Farmer D was the only farmer that considered his DSL as a standalone enterprise. The other farmers were somewhat unsure of the financial performance of their DSL. This suggests that the underlying reasons for DSL ownership relate to risk management benefits and control, as opposed to optimising profitability of the DSL block. Farmer A sums this up by stating his DSL is *"just another way of risk management"*. These findings are consistent with the literature (Bennett, 2013; Davis, 2005; O'Connor, 2003; Postiglione, 2013; Richards, 2006), additionally Richards (2006) found that *"control was king, cash flow certainly wasn't" (*p.50).

Results from this research provide some insight into why control is such a strong driver influencing DSL ownership. In comparison to the average dairy farm in Selwyn District in 2014-15 (DairyNZ & LIC, 2015), all the case study farms had a higher stocking rate per hectare and greater milk production per cow on their MP (table 16). The farmers were focused on achieving high performance levels from their MPs and placed a strong emphasis on growing quality heifers to support this. They generally believed that there was too much volatility involved with relying on external parties for grazing and feed requirements. Ownership of DSL was perceived necessary to enhance the performance of the MP and reduce the risk of jeopardising this performance. The average herd and farm size was also above the district average, and all the farmers owned more than one MP. Farmers C and D were clearly aware that their large operations heavily expose the business to the market. This suggests that larger farm dairy systems in particular are more likely to purchase DSL in attempt to control external risk factors, this is supported by Bennett (2009).

Dalley et al (2008) suggests that previous substandard experiences (growth targets not being met and price volatility) with external graziers often results in farmers deciding the risk of using external parties is too high. This triggered the purchase for Farmer's A and B DSL. Farmer B in particular believed *"you cannot afford to give someone control of your heifers".* This view however, was by no means consistent across the group of farmers. Farmer C was explicit in stating that he was happy with his whole system, which also relies on external support, as he had formed trusting relationships with graziers in the past.

Table 16: A comparsion in size and milk production between the case study farms and the average Selwyn District farm.

	Averages for the Selwyn District 2014-15 (DairyNZ & LIC, 2015)	**Average for the case studies in 2015-16 (milking platform only)***	**Range from the case studies***
Herd size (total number of cows)	738	919	563 – 1,444
Effective hectares (milking platform)	225	254	157 – 399
Stocking rate (cows/hectare)	3.28	3.6	3.4 – 3.9
Milksolid production (kgMS/cow)	411	436	421 – 483
Milksolid production (kgMS/hectare)	1,348	1,579	1,523 – 1,664

**All of the case study farmers owned more than one milking platform. Therefore, these figures are an 'average' milking platform across each case study farmer's total dairying operation.*

In general, all other factors stemming from the purchase were perceived as being secondary in importance, namely flexibility, land appreciation, the opportunity to diversify the business and invest in housing development. Farmer A and D were located close to townships and were aware of the growing demand for housing developments and the potential to capitalise on the investment opportunity.

6.2.1 Summary

Control of feed supply and livestock condition in the overall dairy system was the strongest motivator behind the case study farmers purchasing DSL. All other factors were perceived as secondary in importance, including flexibility, land appreciation, providing a diversified income stream and investment opportunities.

6.3 What are the current management practices used on DSL in Selwyn Waihora?

The DSL case study farms were predominantly used for cow wintering, grazing replacement heifers and producing supplementary feed for the MP. These case studies did not exhibit the diverse management practices defined by Richards (2006), Bennett (2009) and Dalley et al. (2008), for example none of the farmers sold supplements or grazed stock for external parties. Farmer D used some of his DSL for a bull enterprise, however this was only a small (3%) proportion of the farms total revenue and therefore was not considered a significant management practice. Farmer C will use his DSL to grow peas in next year, however again, this is considered a small, complementary management practice. The different management practices and feed contributions made by the dairy support blocks will now be explored.

Research has found that wintering cows is generally the most significant management practice undertaken on owned DSL in Canterbury (Bennett, 2009; Dalley et al., 2008, Peel, 2013; Richards, 2006). Further, per Hockings (2002) and Peel (2013), most Canterbury dairy farmers utilise their MP for lactating cows rather than wintering dry cows, to achieve high stocking rates and productivity in the milking season. This practice has been found to be more profitable than wintering cows on the MP, which results in lower pasture covers during the milking season (Cottier, 2000; Davis, 2005; Hockings, 2002; de Wolde, 2006). Contrary to these findings, cow wintering was not consistent across the case study farms. Farmer C was the only farmer who utilised his block primarily for cow wintering, grazing 15% of his total herd over winter. Farmer B did not utilise his DSL for this purpose due to the block's poorly drained soils and wintered his cows on his neighbours crop purchased as standing. Farmer D also did not winter his cows on the DSL analysed, however all his cows are wintered on another owned DSL block. Farmer A wintered 13% of their herd's total cows, contributing to a small proportion (15%) of the DSLs total grazing revenue. Regardless of where the cows were located over winter (on the DSL block modelled or elsewhere), all the case study farms wintered their cows on forage crops instead of grass or standoff facilities. It is important to consider that three of the farmers (A, B and C) have recently wintered their cows on forage crops on their MPs instead of using a grazier, largely due to the low milk payout. Consistent with Journeaux and Savage (2016), this finding indicates that farmers are willing to sacrifice milk production in order to reduce wintering expenses.

In comparison to the literature findings, replacement heifer grazing was the most significant practice undertaken across the case study support farms. All the farmers, excluding Farmer C, used their DSL for grazing all the replacement heifers of the total dairy enterprise. In respect to these farmers, quality heifers were viewed as integral to the success of their dairying operation and were therefore fed to reach their full potential. Farmer B cited the positive relationship between heifer condition and milk production in the following season.

Three of the study participants (Farmer A, B and C) used their DSL to export feed supplies for use on the milking platform. This 'milking feed' was used primarily to fill feed deficits in the autumn and for transitioning the cows prior to calving. Controlling the availability of this feed, its quality and its pricing, was cited by these farmers as the reason for this DSL and MP interaction. None of the farmers sold supplements to external parties, indicating the inherent feed synergies between the DSL and MPs. This interaction is because the blocks were owned by the same over enterprise and would be different for separately owned MP and DSL.

Research suggests that the relative scale of the DSL to the MP (Richards, 2006), the degree of feed deficiency on the MP (Dalley et al., 2008), and the capabilities of management and the land being farmed (Bennett, 2009), are the key determinants of the range and extent of enterprises that the DSL supports. However, the drivers of the range and extent of enterprises were relatively inconclusive in this research, given the lack of information obtained on the MPs feed deficiency, the similarity of enterprises between farms, and the similar ratio of DSL to MP area (0.3-0.4: 1) between three of the farms (Farm A, B and D). However, it is likely that land use and management capability influenced the enterprises on the DSL to a small extent. For example, wintering activities were constrained by the soil on Farm B, suggesting the capabilities of land being farmed contributes to the enterprises that DSL supports. While Farm C could to winter the largest proportion (15%) of cows on his DSL block due to its intensive cropping rotation, this was supported by the business's joint contracting firm, implying management capabilities drove the intensity of the cropping enterprise.

6.3.1 Summary

The case study farms had three main management practices; replacement heifer grazing, cow wintering and producing supplementary feed for the MP. Contrary to the literature, there was a lack of diversity in management practices undertaken on these DSL. Further, replacement heifer grazing, as opposed to cow wintering, was the most significant management practice undertaken across the farms. There was inconclusive research regarding the key determinants of the range and extent of enterprises that DSL supports.

6.4 How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?

Nitrogen leaching per hectare varied considerably between the four case study farms, ranging from 18.4 to 53.3 kgN/ha/year (average 37.2 kgN/ha/year). This section explores the different management systems that are likely to have contributed to this range of nitrogen leaching.

Research has shown that grazing winter forage crops contribute a disproportionally large proportion of the total nitrogen leached from the total dairy operation (Chrystal et al., 2012; Dalley, 2011; Monaghan et al., 2007; Monaghan, 2012). Consistent with these findings, this study found that on average, although winter grazing represented only 23% of the total DSL area, it was responsible for 57% of the farms total nitrogen losses (figure 9). On average, winter forage crops leached around 134 kgN/ha/year, which over 10 times the level leached from the pasture blocks (12 kgN/ha/year). This implies winter forage cropping practices adversely impact the environmental performance of owned DSL in Selwyn Waihora.

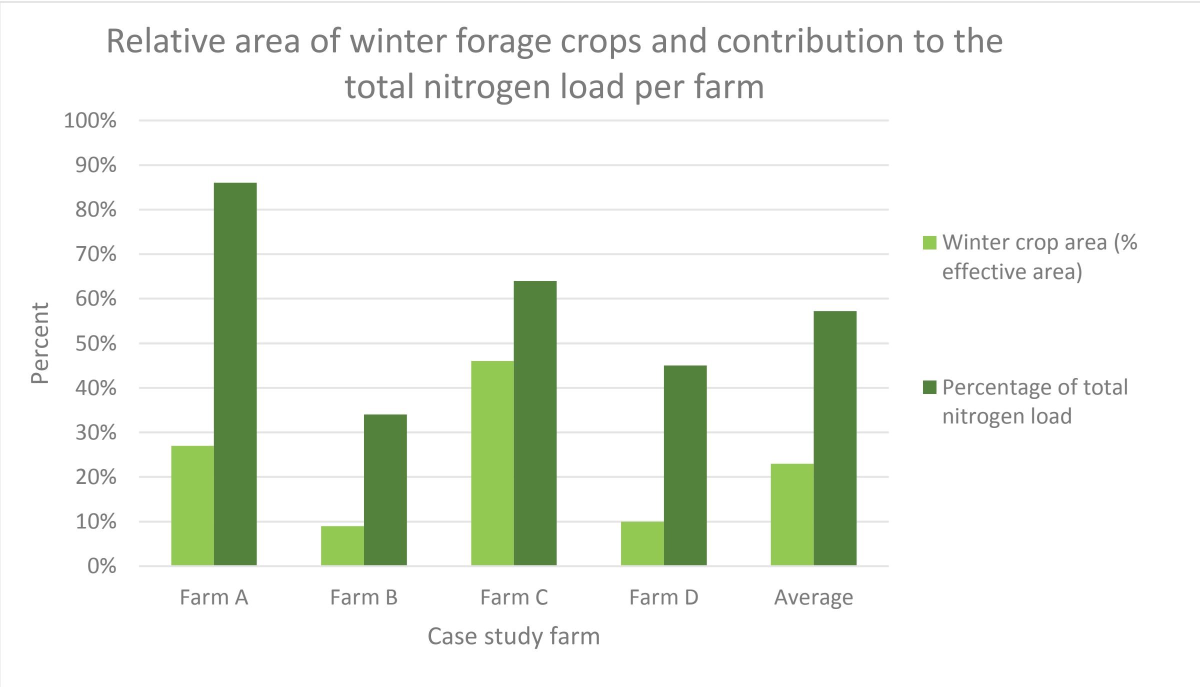

Figure 12: Relative area of winter forage crops and contributiom to the total nitrogen load per farm.

The literature also suggests that forage crop selection impacts nitrogen leaching levels, as feeds with lower CP concentrations reduce dietary and urine nitrogen concentrations

(Edwards, et al., 2014; Farrell, 2015; Gibbs, 2014; James, 2015; Jenkinson et al., 2014). However there is currently inconclusive research into whether fodder beet or kale crops leach more nitrogen (Jenkinson et al., 2014; Farrell, 2015; Ravera, 2014).). Modelling of the base scenario in Overseer estimated that kale leached 55% more nitrogen per hectare than fodder beet on Farm A, while fodder beet leached 78% and 250% more nitrogen than kale on Farms D and C respectively, despite the soil type being consistent across each farm's cropping rotation and the crops having similar grazing durations. It is also important to consider the number of stock each hectare of crop can support (as driven by yield and MJME which is typically higher for fodder beet). In terms of MJME/kgN, the kale crops leached over three times as much nitrogen as the fodder beet crops on Farm A, while the fodder beet crops leached 25% and 62% more nitrogen than kale on Farms D and C respectively. This research does not attempt to predict the reasoning behind these opposing results, but it is worth noting that these estimates are constrained by the assumptions of Overseer (version 6.2.3). Further research into the nitrogen leached from kale and fodder beet crops would help validate these findings.

Research has shown that the use of winter cover crops following forage harvesting could effectively reduce nitrogen leaching, through the uptake of residual nitrogen (Carey et al., 2016; Di & Cameron, 2002a; Fraser et al., 2013; McLenaghan et al., 1996). This study found that forage barley crops which were established following kale or fodder beet (on Farms A and C) leached low concentrations of nitrogen (13 kgN/ha average). Therefore, the use of forage barley as a cover crop has the potential to decrease nitrogen leaching on DSL, however this is dependent on the cover crop being able to be integrated into the existing farm system (for example if the soil moisture suitable to plant crop).

Nitrogen leaching depends on a number of interconnected factors. Therefore, it is difficult to determine the extent that each of these factors contribute to the variation in nitrogen leaching, particularly given the small number of case study farms. The results show weak relationships between nitrogen leaching and stocking rates, irrigation type, nitrogen fertiliser applied to pasture and crop, imported feed and supplements harvested. As previously mentioned, the area of winter forage crop is likely to be the strongest farm management factor driving nitrogen leaching on DSL. However, biophysical factors, as opposed to management factors, are likely to have the most significant impact on the environmental performance of DSL. In particular, soil drainage had a significant influence on nitrogen leaching. Poorly drained soils with high PAW dominated Farm B, which leached less than half of the nitrogen of the other farms. Further, a number of studies have shown large increases of leaching is strongly correlated with decreasing PAW (Brown & Zyskowski 2009; Cameron et al., 2002; Green & Clothier, 2009). While some farm management practices, particularly the area of winter forage cropping, impact on nitrogen leaching on DSL, a much more significant proportion of the nitrogen leaching is determined by biophysical factors (such as soil drainage characteristics) which are beyond the control of farmers.

6.4.1 Summary

A number of interconnected factors determine nitrogen leaching, and it is difficult to determine the extent to which these factors contribute to the variation in nitrogen leaching. Overall, biophysical factors, as opposed to management factors, are likely to contribute to a significant proportion of nitrogen leached from DSL. The proportion of winter forage crop occupying the total DSL area is likely to be the strongest management factor driving nitrogen leaching on DSL. However, this study found inconclusive evidence between farms on whether kale or fodder beet leached more nitrogen (according to Overseer). The use of forage barley as a cover crop improved the environmental performance of the farm.

6.5 How will Variation 1 impact the future physical, environmental and economic performance of DSL?

Environmentally, Variation 1 requires a 22% reduction in nitrogen leaching, this requirement significantly impacted on the physical and economic performance of DSL. The three main farm management practices used across the case study farms were grazing replacement heifers, wintering cows and producing supplementary feed for the MP. Therefore, the relative change in the number of stock on the DSL and supplementary feed exports to the MP were considered key indicators of the physical performance of DSL. Stock numbers were reduced by 5.4% on average across all the farms following the nitrogen mitigation strategies implemented on farm to meet Variation 1. However, there was significant variance (1.9% to 13.3%) between the farms. Farm D was the only farm to experience a change in the amount of supplementary feed exported, as 197 tDM of oats silage was made and sold to an external party. Therefore, in terms of physical performance, Variation 1 is likely to have the most significant impact on the number of stock that DSL can support. If farmers do reduce stock numbers on DSL to meet these nitrogen leaching restrictions, there will be less DSL available in the Selwyn Waihora catchment. Therefore, it is likely that dairy farmers will have to increase their owned DSL area, or source alternative grazing for their surplus stock. This could be on farms that can increase their nitrogen leaching under Variation 1 (for example dryland sheep and beef properties operating under the nitrogen baseline) or in areas which are yet to implement nitrogen limits. Overall, these findings suggest that Variation 1 may result in DSL not meeting the purpose it was purchased for; to attain control over livestock condition and to reduce the volatility involved with relying on external parties for grazing replacement heifers and wintering cows.

The results of this study are based on Overseer, and as such this research focuses on analysing the relative changes in nitrogen loss and operating profit (as measured by EBIT) between the mitigations, as opposed to the absolute values, as recommended by Cichota and Snow (2009). The results from the nitrogen mitigation modelling found that Variation 1 resulted in 11.3% reduction in operating profit on average (figure 10). However, the response of individual farms was highly variable according how much nitrogen they had to reduce (based on their position relative to the 15kgN/ha threshold) and the farm’s existing management practices which determined what mitigations could be implemented. This finding is consistent with the literature, which has indicated that the relative change in operating profit following nitrogen mitigation is inherently different for each individual farm system (DairyNZ Economics Group, 2015; DairyNZ, 2013b; Kaye-Blake et al., 2014; Perrin Ag, 2015; Smeaton et al., 2011; Vibart et al.,2015; Vogeler et al., 2014). Farm A experienced the largest reductions in operating profit (37%), due to sizeable reductions in contract grazier revenue and increases in silage making expenses. Farm C also experienced a significant decrease in operating profit (12.2%), largely due to decreases in contract grazing revenue and supplementary feed sales. In contrast, Farms B and D experienced small increases in operating profit. Farm B had a low nitrogen baseline and was only required to reduce nitrogen leaching by 18.5%. This farmer experienced large reductions in total expenses (mostly crop and nitrogen fertiliser costs), while Farm D benefitted from the revenue derived from the introduction of cereal silage sales. The reduction in these expenses offset the decrease in revenue on these two farms. On average, over 60% of total revenue was derived from contract grazing for the case study farms. Consequently, mitigation strategies that decreased the number of stock on the DSL generally imposed significant financial risk to the DSL businesses. This is supported by a DairyNZ (2013b) modelling study by which assessed the impact of nutrient allocation limits on DSL.

The implementation of a stand-off pad will also have significant impacts on the future physical and economic performance of DSL. In terms of physical performance, the amount of supplements exported from the DSL to the MP was reduced by 3.6% on average (ranging from -21 to +11%). Stock numbers however remained constant across the farm, which is desirable for farmers who have purchased DSL primarily to attain control of all their stock. However, the stand-off pad mitigation had significant adverse impacts on the operating profit on DSL. Nitrogen leaching was reduced by 15%, resulting in a 53% reduction in operating profit. Relative to the nitrogen mitigation protocol, the stand-off pad mitigated 50% less nitrogen and resulted in an operating profit that was more than 3.5 times lower. It is however, important to remember that some case study farmers explicitly stated that maintaining control over animal condition was more important than generating a return from their DSL.

The nitrogen mitigations used in this study focused on altering fertiliser, imported supplements and crops, as well as implementing a stand-off pad. Therefore, the impact of these mitigations is largely dependent on the costs of inputs related to these mitigation options. These mitigations are also likely to be very sensitive to the contract grazier payment which directly impacts revenue for many DSL farms. Further research should test the sensitivity of these key assumptions used in this research, in particular contract grazier price. In reality, the case study farms are not operating as standalone units, however the contract grazier price is important as it represents the price that would be required if the DSL was not owned.

This study used consistent costs for the grazier payment, cropping, regrassing and supplements, which may differ from the individual farmers, and supplements, which may differ from the individual farmers, suggesting the relative changes in operating profit are more useful in interpreting the results than the absolute values. However, in absolute terms, there was a wide range of starting levels for operating profit, meaning the same percentage change on these farms does not necessarily equate to the same reduction. For example, relative to Farms B and D, Farm C experienced a larger percentage reduction in operating profit yet had over twice as much operating profit.

It is important to consider that the absolute level of operating profit after meeting the Variation 1 requirements must be enough for a DSL farmer to meet other payment obligations including interest, tax, debt repayment and any reinvestment required in the farm. The financial analysis used for the standardised nitrogen mitigation protocol in this study excluded these payments to allow comparisons between farms. However, farms that may appear financially viable after meeting Variation 1 requirements may no longer be viable when these other payments are accounted for. This was shown when the interest cost associated with the stand-off pad structure was added to the operating expenses, as operating profit was reduced to almost zero for Farms B, C and D, while Farm A became financially unviable. This study recommends that an investment analysis is undertaken when considering capital intensive mitigations such as a standoff pad. In addition farms should consider their full business obligations when choosing how to meet Variation 1 requirements instead of looking just at operating profit.

6.5.1 Summary

Variation 1 is likely to have a significant influence on the number of stock the DSL can support, suggesting DSL may not meet the purposes it was purchased for in the future; to achieve control of livestock condition and eliminate volatility in grazing and feed costs. Overall, average operating profit is estimated to reduce by 11%, following implementation of the nitrogen mitigation protocol. The stand-off pad mitigation performed significantly worse environmentally and economically, however this mitigation allowed physical performance to remain relatively constant, particularly in stock carried. This research made some assumptions in relation to the cost of key inputs. In addition, focus is placed on relative change in operating profit following nitrogen mitigation, rather than a full financial analysis and absolute changes. It is important to read the results in relation to these assumptions and limitations.

6.6 How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

Farmers need to understand how to meet their nitrogen constraints in the most cost effective manner, while this research has shown that they may chose an alternative mitigation strategy based on their primary purpose for having DSL, understanding the most cost effective way will allow them to make an informed choice in response to Variation 1. This is related to Howarth and Journeaux (2016) and Ledgard et al. (2006) who found nitrogen mitigations have differing effectiveness based on the farm they are applied on. For example, mitigation effectiveness differed between crop types on the same farm and the same crops on different farms. On Farm A, kale leached more than fodder beet, while both Farms C and D had higher nitrogen levels leached from fodder beet crops than on kale. This study also found that the establishment of a cover crop on Farm B increased nitrogen leaching, while the same cover crop reduced leaching on Farm D. Further, the replacement of high CP imported supplements which had a lower CP content had no impact on nitrogen leaching on Farm D. These findings highlight the importance of the farmer assessing the effectiveness of nitrogen mitigations before making significant and unnecessary farm system changes. Certified farm nutrient management advisors can provide this service and are likely to be highly valuable to farmers, as they meet their obligations under Variation 1. Improved simulations by future versions of Overseer are also likely to provide better understanding of the mitigation interactions.

Some mitigations were not applicable on the case study farms. For instance, Farm D had an intensive cropping rotation, therefore there was no scope to reduce pastoral nitrogen or establish cover crops. Likewise, Farm A and C only imported straw (a low CP feed), while Farm B did not import any supplements, therefore the diet manipulation of imported supplements was not applicable to these farms. Overall, the number of mitigations available to the farmer impacts their ability to be able to select the most appropriate way to reduce nitrogen for their business.

The cost-effectiveness of the mitigations used in the nitrogen mitigation protocol were analysed. This was determined by dividing the annualised net cost of each option by the quantity of nitrogen conserved (over the total farm area). On average, it cost $12 to conserve a kilogram of nitrogen using the nitrogen mitigation protocol. However, this varied significantly between farm. Farm C had the lowest cost efficiency (-$48/kgN), possibly due to the intensive cropping operation limiting the number of mitigations available. In comparison, the Farm D had the highest cost efficiency and gained $9 per kilogram of nitrogen conserved. This farm was unique as an oat cover crop was established (among other mitigations), which increased revenue from the sales of oats silage significantly. This finding indicates that cover crops are likely to play an important role in allowing farmers to meet their nitrogen constraints while not undermining the economic performance of their farming business.

In addition, the cost-effectiveness of the nitrogen mitigation protocol was compared with the stand-off pad mitigation. This study found that on average it cost $175 per kilogram of nitrogen conserved from the stand-off pad mitigation, these costs were based on Brown (2014) who estimated that it cost $171 per kilogram of mitigated nitrogen leached from the establishment of a stand-off pad structure on the Ashley Dene Research Farm. Generally, this mitigation option was more cost-effective if the stock were only wintered on crops (rather than crops and grass) on the existing system (as pasture did not need to be cut and carried to the cows on the stand-off), and if the stock were able to utilise the stand-off pad for several months. Overall, the nitrogen mitigation protocol was 14 times more cost-effective than the stand-off pad structure (excluding interest). Debt servicing will be significantly higher from the standoff mitigation as opposed to the nitrogen mitigation protocol which requires no additional capital investment. It is therefore strongly recommended that farmers undertake a full investment analysis on a capital investment to reduce nitrogen leaching relative to non-capital intensive mitigation options.

The farmers perceptions on how Variation 1 will impact their farming business is also useful to explore as this, combined with their reasons for purchasing the DSL, provides insight into what mitigation options may be preferential. Farmer B showed apprehension towards the rules and believed it would have significant implications on his DSL and wider farming business. Farmer C was more positive towards the change, and stated that he may have to reduce the intensity of his DSL and reduce the number of wintered cows, but he would *"just farm…(his) way around it".* Despite its low cost-effectiveness, some farmers may choose to invest in a standoff pad as their first option to mitigate nitrogen losses as it allows them to remain more intensive. This is particularly true for those farmers who want to attain optimal control of their total dairying operation, and therefore eliminate the volatility associated with relying on external parties for support. This is important as it shows that farmers will not all chose to meet their Variation 1 requirements in the same way. This will be based on farmer perceptions and preference which is largely tied to their decisions to purchase the DSL.

Despite acknowledging that farmers may not all chose the most cost effective mitigation option, it is important to understand what this is in order to help inform farmers deciding how to respond to Variation 1. Therefore, this study has explored the impact if farmers use the most cost effective option. However, the mitigations implemented for each farm did account mitigations identified by the farmer as potentially favoured mitigation strategies. In particular, Farmer D emphasised the importance of reducing the fallow period over winter and utilising nitrogen with oat cover crops, which was consistent with the mitigation employed on his farm. Overall, this suggests that the farmers are already aware of the most cost effective mitigation available according to the constraints of their farm system.

Some of the farmers mentioned mitigations that they have adopted in order to reduce nitrogen (among other things), despite their lack of recognition by Overseer modelling. For instance, Farmer A and C have established diverse pastures, however this mitigation is currently not recognised by Overseer. This highlights that farmers are well informed of the suite of mitigation options to reduce nitrogen leaching, and emphasises the need for Overseer to continue to incorporate empirical research into the model to ensure that the farmers can benefit from these relatively new mitigations. Farmer B and C expressed their preference towards DCD if it came back on the market, suggesting that there is hope for the 'silver bullet' among farmers.

6.6.1 Summary

The cost-effectiveness of nitrogen mitigation largely depends on the context of individual farm systems; there is no 'one size fits all'. Therefore, farm advisors are likely to be highly valuable to farmers in assessing the cost-effectiveness of nitrogen mitigations (according to Overseer). The nitrogen mitigation protocol was significantly more cost-effective than the stand-off pad ($12/kgN and $175/kgN respectively). The establishment of an oats cover crop was the most cost-effective way to reduce nitrogen leaching, however this mitigation was applicable to only one farm. The case study farmers were generally well informed with respect to the mitigation options available to reduce nitrogen, and the most cost-effective option available according to their farm system. Most importantly this study reiterates the importance of farmer preference in selecting mitigations that fit in with their overall business drivers and goals and therefore some farmers may not choose the most cost effective mitigation, instead prioritising factors such as control over stock.

Chapter 7
Conclusions

The objective of this research was to examine the implications of nitrogen regulation on the performance of DSL in the Selwyn Waihora catchment, and in doing so, address a gap in the literature. The intention was to assist farmers in making informed decisions when considering how to meet their obligations under Variation 1, and to help inform policy creation in other areas and direction for future research.

Four dairy farmers that owned DSL in the Selwyn Waihora catchment were interviewed to obtain physical, financial and environmental data, as well as qualitative information pertaining to DSL ownership. Farm system modelling was used to identify the abatement cost of reducing nitrogen leaching under Variation 1, this used Oversee and Farmax. The lowest cost mitigation strategies were used, in addition to a stand-off pad structure.

This research found that Variation 1 is likely to have significant impacts on the future physical performance of DSL in Selwyn Waihora. Winter forage cropping was an integral component of all the DSL farms. However, the proportion of winter forage crop occupying the total DSL area was the strongest management factor increasing nitrogen leaching on DSL. Consequently, the mitigations were largely focused on reducing the losses of these crops. Stock numbers were reduced by 5.4% on average across all farms following nitrogen mitigation. This suggests that there will be a decrease in the availability of DSL in the Selwyn Waihora catchment as DSL reduces the stock they carry over winter to reduce their nitrogen leaching. This would also impact on the ability of DSL to meet a common primary objective of purchase; to attain direct control the condition of livestock and therefore, enhance the performance of the overall dairy system. This will have many flow-on effects in the wider agriculture industry, requiring additional support from third party graziers.

Mitigating nitrogen leaching from DSL was shown to reduce operating profit; this report estimates that a 22% reduction in nitrogen leaching will reduce operating profit by 11%, on average. The stand-off pad structure was only able to reduce nitrogen leaching by 15%, reducing operating profit by 53.1%. Overall, the iterative nitrogen mitigations used were significantly more cost-effective than the stand-off pad ($12/kgN and $175/kgN respectively). The establishment of an oat cover crop was the most cost-effective way to reduce nitrogen. However, the qualitative information gathered from the case study farmers indicates that DSL farmers may not chose the most cost effective mitigation, instead prioritising other benefits such as control of stock and minimisation of exposure to price risk.

The physical, economic and practical implications of nitrogen regulation were highly variable across the four case study farms, according to the differences in farms current nitrogen baseline and the existing management practices. Further, the mitigations had differing cost-effectiveness based on the farm they were implemented on. This highlights that there is no 'one size fits all' approach to mitigating nitrogen losses from farms, as these factors need to be considered on a farm specific and farm system basis and in conjunction with the farmer's business strategy and preferences. Making assumptions on how an "average" DSL farm may respond to nitrogen policy may be erroneous.

Chapter 8
Limitations

One limitation of this research is that it does not reduce nitrogen leaching losses from the baseline (2009 to 2013) average, as required by Variation 1. Rather the baseline was set as the current 2015-16 season, as two of the farmers had purchased their DSL properties after 2011 and did not have access to the previous farmers fertiliser, stock and feed records to create the Overseer baseline model. Although this is not the ideal situation given the policy context, it was a necessary starting point for this research given on data available. This approach allowed consistency between farms and was considered more accurate than basing the baseline on anecdotal assumptions of the farming system operated by the previous owner. This study does not attempt to predict what the regional council may do in situations similar to these.

The research approach uses case study farms. While this provides real data for each farm and covers a wide range of biophysical and farm system characteristics, the degree of which the farms are representative is uncertain. This is particularly the case given the absence of robust, accessible data on the range of DSL systems in Selwyn Waihora or the wider Canterbury region. In comparison to the production averages in the Selwyn District in 2014-15, all the MPs owned by the case study farmers had a higher stocking rate per hectare and greater milk production per cow. The average herd size and farm size was also above the district average, and all the farmers owned more than one dairy farm. Further, all the case study farmers were considered good farmers with a good grasp on farm management, animal nutrition and financial management. In this respect the sample shows a degree of bias towards larger, higher producing farms and above average farmers. However, this study does not attempt to seek definitive answers that reflect the position of all Selwyn Waihora DSL farmers. Rather it is hoped that the results from this research can be utilised by farmers to support decisions in selecting and implementing mitigation strategies to their own farm system.

This research is limited by the assumptions and constraints of Overseer. The key assumptions underpinning the model are described in section 3.4.1. The Overseer technology is an iterative process, as new versions of the model are continually released. These changes are representative of the move to constantly improve the science supporting the model. Although this is desirable, each new version of Overseer can result in significantly different leaching outputs from the same model inputs creating uncertainty over environmental performance and requirements to meet Variation 1. The results of this study are based on Overseer version 6.2.3 and as such this research focuses on analysing the relative changes in nitrogen leaching and operating profit between the mitigations, as recommended by Cichota and Snow (2009).

Another constraint of Overseer is that some mitigations (for example diverse pastures) have not yet been incorporated into the model and were therefore unable to be included as mitigations. Attempts were made to determine the assumptions driving the opposing results of kale and fodder beet leaching between farms. However, a review of the Overseer documents proved it was difficult to obtain all the assumptions and operational aspects of Overseer, although some assumptions are disclosed in various places. Further, while the Overseer Input Standards outline how to establish an Overseer file based on actual farm data, they do not provide guidance on how to complete scenario analysis (Howarth & Journeaux, 2016), such as mitigation modelling. However, despite the concerns in relation to the assumptions, limitations and accuracy of Overseer, it is considered the best method available for determining farm level nitrogen leaching and at this stage is mandatory for the regulation of nitrogen leaching on Canterbury farms.

A limitation with Farmax is that it does not determine if the CP requirements are met by the modelled diet, this is important as New Zealand pastoral systems typically have excessively high protein contents (Pacheco & Waghorn, 2008). Rather, Farmax assumes that energy is the most limiting factor to livestock production. In reality, Farmax may have overestimated the condition of the livestock if their diets were CP deficient, especially during the wintering period where fodder beet is a large proportion of the diet.

This research used Overseer and Farmax modelling simultaneously to identify the implications of reducing nitrogen leaching. However, these two models are not directly linked and do not provide an optimised environmental and economic solution, so an iterative process was required to achieve the optimal mitigation option (Smeaton et al., 2011). This has been recognised as manually intensive and somewhat subjective (McCall, 2013; McEwen, 2015). This process however, was important to ensure the farm system created was biologically feasible and the allowed the physical, financial and environmental impact of mitigation strategies to be analysed.

A range of assumptions were used for the mitigation modelling (refer to section 4.5.3). In particular, the lowest cost mitigation strategies were used given the modelling constraints. However, the qualitative information from the case study farmers indicated that they may choose alternative mitigations to ensure their control of stock is maximised and price exposure minimised. Using the lowest cost mitigation option is unlikely to be a major limitation, given that the mitigations implemented for each farm were broadly consistent with the mitigations identified by the farmer as their preferred mitigation strategies. This modelling did not consider land use intensification or land use change. Further, mitigations that would require improved skill and management capability were largely excluded, as the determining the cost of changes in farmer capability was unable to be captured accurately.

The mitigations used in this research will have a wide distribution of impacts, dependent on the context and constraints of the individual farm system, for instance skills of farm management and labour, the quality of resources, or the debt level of the farmer. The mitigation strategies, may be difficult to achieve in practice, and may require significant capital expenditure or increases in skills (Smeaton et al., 2011). In particular, the standoff pad mitigation is likely to result in many changes to the farm system (for example reduction in soil pugging and changes in animal welfare). Further, changes to crops types and rotations are likely to have a range of practical implications surrounding livestock transitioning and the timing and planning of crop establishment. While this study has modelled the farm system in a holistic way, predicting the impacts of mitigations on all of these factors is difficult and beyond the scope of this study.

The economic analysis for this research assumed that the DSL was a standalone business, however in reality three of the farmers considered their DSL as a component of the overall dairying business. Neither does this study assess the environmental performance of the overall dairying enterprise (MPs and DSL). However, Variation 1 explicity separates different land uses which require different levels of nitrogen loss reductions. As a result, it is both necessary and relevant to analyse the DSL as a standalone enterprise.

The financial analysis focused on changes in operating profit which includes cash expenses and depreciation. Excluding interest and tax enables the farms to be comparable, however, farms that may appear capable of meeting the cost of nitrogen mitigation may in reality become financially unviable when interest, and other payment obligations, are accounted for. Because these costs were excluded from this study, the financial results need to be interpretted with this in mind.

Despite these limitations, this research can be informative for farmers and policy and provide a starting point for future research. It is important, however, to read the results of this research in relation to the assumptions and limitations, particulary when extrapolating these results to DSL in the Selwyn Waihora catchment and the wider region.

Chapter 9

Recommendations

9.1 Recommendations for future research

1) Further research should test the sensitivity of some key assumptions used in this research, in particular contract grazier price, input prices (including feed prices) and the cost to establish a standoff pad structure.

2) A subtlety revealed in this research was the negative regard for the additional monitoring, recording and reporting that has come around as a result of nitrogen regulation. Further research should examine the desire of farmers to continue to farm in a more regulated and compliance focused environment as well as how farmers could be motivated to undertake these practices

3) This research found that Variation 1 is likely to result in a reduction in stocking levels on owned DSL. Further research could examine the flow on effects of this change, in particular where the stock will go and the impacts on the overall dairying enterprise. To enable this, there is a need to have a better understanding where the 161,000 cows in Selwyn Waihora are wintered at present. Having good statistics around the location of winter grazing would also assist future policy development in Selwyn Waihora. A better understanding of who the graziers providing support to the dairy industry are, could help develop targeted education activities focusing areas such as BCS monitoring, feed/crop assessment, and winter feeding management including the crop transitioning period. As a result of Variation 1, there is an increased need for both parties to be able to establish and maintain a successful relationship with mutual benefits.

4) Further research should be conducted to support the contentious nitrogen leaching debate surrounding 'kale versus fodder beet', and validate the inconclusive findings found within this research as to what crop leaches more given the farm context and why.

5) The results showed that an oat cover crop has the potential to enhance the environmental and economic performance of DSL. Further research needs to validate this finding across a number of farms and investigate how farmers could incorporate this practice into their farm system.

9.2 Recommendations for farmers

1) This research highlights the inherent variation in the environmental and financial effectiveness of nitrogen mitigations between farms. It is important farmers evaluate the effectiveness of mitigations before making significant and unnecessary farm system changes. As a result, it is strongly recommended that farms use a certified farm nutrient management advisor in assessing the effectiveness of nitrogen mitigations (according to Overseer).

2) The financial analysis used in this study excluded interest, tax and debt servicing, to allow comparisons between farms. However, farms that appear financially viable following nitrogen mitigation, in reality, may become unviable when these costs are accounted for. This study recommends that an investment analysis is undertaken when considering capital intensive mitigations such as a standoff pad. In addition farms should consider their full business obligations when choosing how to meet Variation 1 requirements instead of looking just at operating profit.

3) Variation 1 requires nitrogen leaching losses to be reduced from the 2009-13 baseline, and ECAN requires farmers to have completed a baseline by next year. However, only one farmer had a completed baseline from a farm advisor. Two of the remaining farmers purchased their properties after 2011 and did not have access to the previous farmer’s farm records. This highlights the importance of farmers keeping annual fertiliser, stock and feed records for nitrogen regulation purposes.

9.3 Recommendations for policy

1) Regional councils yet to implement on-farm nitrogen discharge limits under the NPSFM need to consider the impact of nitrogen regulations on DSL, while accounting for the variation of farms. The methodology presented here provides a starting point for this analysis. Land use change and the impact of land values will also need to be

considered and the methodology used in this research will need to be expanded to account for this.

2) This study found that the operating profit on DSL will be negatively impacted from Variation 1. There is potential for this to cause issues with the financial viability and equity position of farms, and in extreme cases forced sales and bankruptcy. It is strongly recommended that regional councils consider the total financial impact of these nitrogen regulations when undertaking a section 32 (RMA) analysis of their proposed policies, to ensure that the most desirable policy for the community is implemented.

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Charlotte Irving
Lincoln University

Appendix 1: Farmer Questionnaire

Date: ___________________________

Farm Business Details						
Primary contact name						
Farmer phone number						
Farmer email address						
Support block physical address						
Milking platform physical address(s)						
Milking platform total effective area (ha)	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Business structure *(circle one)*	1. Owner operator 2. '50-50' sharemilker 3. Owner with '50-50' sharemilker 4. Owner with variable order or contract milker					
Production system type (on milking platform) *(circle one according to farmer)*	1. All grass self-contained, all cows on dairy platform for the year/0% of total feed imported 2. Feed imported for dry cows, or cows grazed off/4-14% total feed imported 3. Feed imported to extend lactation (typically autumn) and for dry cows/10-20% total feed imported 4. Feed imported to extend both ends of lactation and for dry cows/21-30% total feed imported 5. Imported feed used all year/25+ total feed imported					

Farm Description (support block) *If available, attach a farm map showing area of pasture, crop, effluent applications, and irrigation (by type e.g. pivot, k-line) to help block the farm on Overseer. Also, attach a separate map of fertiliser applications (area, timing, rate of application).*	
	Hectares
Total effective area Total pasture area Crop 1___________________________*(specify type)* Crop 2___________________________ Crop 3___________________________ *(Refer to page 16 for crop rotation information)*	
Ineffective area Including buildings and farm tracks + wetlands + trees and scrub + riparian fenced or retired	
Total farm hectares (effective + ineffective)	
Farm topography - Flat (ha) - Rolling (ha) - Rolling-steep (ha) - Steep land (ha)	
Is irrigation applied to the farm? **If so how many hectares of the following irrigation types?** - Centre pivot/lateral - Travelling irrigator - Sprinkers (K-line)	

- Border dyke	
Does the farm have artificial drainage? If so how many hectares, and what type of drainage?	
Occurrence of pugging on farm? *(circle)*	○ Rare ○ Occasional ○ Winter ○ Winter or rain

Soil fertility (if known)

*Soil test results date*______________________________*(specify)*

	pH	Olsen P (mg/mL)	Ca (QTU)	Mg (QTU)	K (QTU)	Na (QTU)	Sulphate (ug/g)	Organic Sulphur	CEC (me/100g)
Average									
Range									

Fertiliser application regime on the farm (pastoral only)

Fertiliser company____)*(specify)*

Fertiliser type *(e.g. urea, DAP)*	Area applied *(state if eff/non-eff block)*	Rate *(kg/ha)*	Application date	Response rate (kgDM/kgN) *(if known)*	Method of application *(e.g incorporated, top dressed)*

Effluent application (if applicable)

Is effluent is applied to the farm please answer the following, and highlight area on a farm map:

Hectares effluent applied to												
Depth of application *(if known)* **OR** rate of application (mm)	Depth of application ____________(mm) **OR** ○ Very low ○ Low ○ Medium ○ High											
Months of application: *(tick)*	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
Is effluent collection:	○ Spray from sump **OR** ○ Holding pond (more than 3 days storage all year) **OR** ○ Other _______________(specify e.g. all exported, 2 pond discharge)											
Is solid effluent separated before the pond?	Yes / No											
If solids are separated, are the stored undercover?	Yes / No											
How often are solids removed?	Every _____ years											
Where are solids disposed of? *(e.g. off farm, effluent block, non-effluent block)*												
What months are pond solids disposed of? *(tick)*	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May

Irrigation activity (not including effluent spread on pasture) *Is irrigation is applied to the farm please answer the following, and highlight area on a farm map:* Water supplier ______________________________*(specify)*				
Irrigation type	Hectares of irrigation type	Months typically irrigated	Application depth (mm) OR total water applied to farm (mm)	When deciding to irrigate do you use: 1. Soil moisture probe (include depth buried) 2. Soil moisture tape (include depth buried) 3. Soil water budget 4. Visual assessment/dig a hole 5. Fixed depth and return period
- Centre pivot/lateral				
- Travelling irrigator				
- Sprinkers (K-line)				K-line is shifted: A: Once a day **OR** B: Twice a day
- Drip/micro irrigation				
- Borderdyke				

Pasture *Please attach any measurements of pasture covers or growth rates throughout the year*	
Dominant pasture type	
Hectares of new pasture grown/year Date new pasture is sown	
Annual pasture production (tDM/ha) *(if known).* Is this measured or a guess?	
Are there differences in pasture productivity across the farm? *(e.g. depending on eff/non-eff, irri/non-irri, different soil types and terrain)*	

Other comments on pasture growth patterns (when growth picks up, months of peak growth, when growth drops, growth in winter):

Stock description	
Peak milking cow numbers (10-day average)	
Dominant cow breed	
Breeding worth	
BCS/weight at dry off	
BCS/weight at calving	
Average weight (1st December)	
Total milk production	
Peak milk production per cow (kgMS)	
Date of peak milk production	
Once a day milking	○ Yes (if so, what date does once a day milking start, is it staggered?) ____ ○ No
Final dry off date	
Average days in milk per cow	

Stock reconciliation

Please attach annual stock reconciliation

Insert stock numbers and circle when stock are on the support block (if not circled they are assumed to be on milking platform)

Stock classes	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
Mixed age cows												
R2 heifers												
R1 heifers												
Heifer calves												
Bull calves												
Bulls												
Other stock e.g sheep ___________*(specify)*												
Other stock ___________*(specify)*												

Key events (deaths, purchases, sales) and location for stock

Please insert numbers and if known the months the events occur
Make sure the days the stock are on the support block are obtained

Stock classes	Location *(e.g. August-May on milking platform, 500 cows to third party (3rd June - 5th August), 430 cows low condition cows to owned runoff (1st June-1st August)*	Deaths (number or %)	Sales (e.g. to works)	Purchases
Mixed age cows	*Refer to Appendix 1 if herds are staggered on and off support block/milking platform*			
R2 yearlings (heifers)				
R1 calves (heifers)				
R1 bull calves			*Are all bull calves sold at 4 days old?*	

Bulls				
Other stock (e.g. sheep) ____________________ *(specify type and age*				
Other stock ____________________ *(specify type and age*				

Feed inventory for mixed age cows on support block							
	Feed offered (kgDM/day)						
	Pasture	Silage	Straw	Baleage	Crop 1	Crop 2	Other__________
Utilisation rate *(if known)*							
MJME/kgDM *(if known)*	*(Can use regional averages)*						
Month	Feed offered (kgDM/day)						
June							
July							
August							
September							
October							
November							
December							
January							
February							
March							
April							
May							

Feed inventory for young stock on support block

Stock class____________________*(specify)*

	Feed offered (kgDM/day)						
Month	Pasture	Silage	Straw	Baleage	Crop 1	Crop 2	Other_________
June							
July							
August							
September							
October							
November							
December							
January							
February							
March							
April							
May							

Comments on feed inventory for other stock (e.g. bulls, calves)

Pasture supplements grown on support block (excluding cash and forage crops)						
Pasture supplement	Area harvested (ha) *	Expected yield (tDM/ha)	Block supplements are made *(irrigated/effluent/high fert)*	Date out of grazing rotation	Date back to grazing rotation	Destination of feed *(fed on support block, exported to milking platform or sold)?*
Hay Cut 1 Cut 2 Cut 3 Cut 4						
Pasture silage Cut 1 Cut 2 Cut 3 Cut 4						
Baleage Cut 1 Cut 2 Cut 3 Cut 4						

Crops grown on support land

Crop 1 ______________________ *(specify crop type) Hectares* __________ *Expected yield* ________ *Crop cost ($/ha)*__________*(if known)*

Month		Month cultivation started and crop sown *Include if previously crop/pasture and if pasture/crop follows*	Feriliser applied *(type, rate (kg/ha), and method of application)*	Irrigation applied and type *(e.g pivot)*	Defolitation method *(e.g. grazed in-situ 8 hours a day by mixed age cows)*
Last season	June				
	July				
	August				
	September				
	October				
	November				
	December				
	January				
	February				
	March				
	April				
	May				
Current season	June				
	July				
	August				
	September				
	October				
	November				
	December				
	January				
	February				
	March				
	April				
	May				

Imported supplements

(Includes supplements purchased/imported from milking platform or external parties)

Supplement type	Total brought *(tDM/wet matter)*	$/unit *(specify unit)*	Date purchased	Average MJME/kg DM *(if known)*	Utilisation rate *(note if it differs by block/month)*	Opening and on hand 1st June	Closing on-hand 31st May	Purchased from milking platform/external party?	Storage method

Off-pasture structures on the support block (if applicable) Structure type _______________________*(e.g. feed pad, wintering pad, stand-off pad)*												
	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
# of days structure used												
# of cows using structure												
# of hours/day structure used												
Feed type on structure												
Kg DM/cow/day of feed fed on structure												

Is the structure covered or uncovered?	Covered / uncovered
Structure surface/ bedding:	
Is surface scraped regularly?	Yes / No
How long is solid effluent in storage before disposal (months)?	
Are solids separated?	Yes / No
Are solids in storage open to rain or covered?	
Is the surface scrapped or flushed with water?	Scrapped / flushed with water
Where and when is solid effluent spread (e.g. effluent block, exported off farm)	

Appendix 1: Mixed age cows grazed on support block				
	Number of cows	Date moved from milking platform to support block	Date back to milking platform	Total days grazed off
Herd 1				
Herd 2				
Herd 3				
Herd 4				
Herd 5				
Return to milking platform policy	Cows return to milking platform _______ to _______ days before calving.			
Young stock grazed on support block				
	Number of cows	Date moved from milking platform to support block	Date back to milking platform	Total days grazed off
Herd 1				

Operating profit

If you grazed your heifers and/or cows using a third party grazier how much would you expect to pay?	

Farm Working Expenses (support block only, excluding milking platform)

Expense category	Total $ *OR* $/ha *OR* $/cow
Wages (include management wage)	
Animal health	
Electricity	
Feed - Net feed made - Net supplements purchased - Net cropping costs	
Fertiliser	
Irrigation	
Regrassing	
Weed and pest	
Plant and machinery	
Vehicles and fuel	
Repairs and maintenance	
Freight and cartage	
Administration	
Insurance	
ACC	
Rates	

Comments on expenses (e.g. type, size and age of machinery, total labour units, interactions with the milking platform)

____

Land valuation (if known)	
Rateable land value ($) and date valued	
Rateable capital value ($) and date valued	

Part 3: Qualitative Questionnaire

Background

- Outline the history of the support block (date purchased, management changes from previous years).
- How does your runoff support your milking platform?
- What were the primary reasons for purchasing the support block?
- Have you considered other grazing options (third party grazier/leased support block)?
- What are the key benefits associated with owning dairy support land?

  (e.g better stock management/control, labour utilisation, land appreciation, flexibility when sending cows off)?
- What are the key challenges associated with owning dairy support land?

  (e.g. finding experienced labour, exhausted labour, lack of time, resources, energy and money, nitrogen regulation, soil pugging)

Nitrogen regulation

- Are you aware of Variation 1 of the Land and Water Regional Plan, and the rules?
- Have you had a nitrogen baseline completed (N leached 2009-2013)? If so what is it, and is it likely for me to get a copy?
- What are your goals and objectives for the future? Does nitrogen regulation limit these goals?
- What are your thoughts of Selwyn Waihora's nitrogen regulations, and do you think it will impact your dairy support system being able to achieve its purpose, or the future value of the land?
- What previous actions (i.e. changes to farm management practices) (if any) have been undertaken to mitigate nitrogen on your DSL farm?
- What is your preferred nitrogen mitigation strategy/farm system preference?

Appendix 2: Kale direct costs

Category	Date	Operation	Product	Rate	Unit			Cost/ha	Sub-total
Seed		Seed		4	kg	@	$20	$80.00	$80
Establishment		Cultivation	115 kW tractor	1.3	hour	@	$141	$183.00	$242
		Drilling		0.5	hour	@	$141	$71.00	
Fertiliser		Fertiliser	DAP Bo Boost	200	kg	@	$1.04	$208.00	$364
		Fertiliser	Urea	300	kg	@	$0.46	$138.00	
Weed, pest and disease	Pre-drill		Roundup	4	l	@	$4.18	$16.70	$313
	Pre-drill	Insecticide	Lorsban	2	l	@	$21	$42	
	Pre-drill	Insecticide	Pulse	0.4	l	@	$24	$9.60	
	Pre-drill	Application	Contract sprayer	1		@	$24	$24.00	
	Post-drill		Karate	0.04	l	@	$466	$18.64	
	Post-drill	Insecticide	Lorsban	1.2	l	@	$21	$25.20	
	Post-drill	Insecticide	Pulse	0.4	l	@	$24	$9.60	
	Post-drill		Dicamba 500 SL	0.3	l	@	$40.54	$12.16	
	Post-drill	Application	Contract sprayer	1		@	$24	$24.00	
	During growth		Ampligo	0.1	l	@	$412	$41.20	
	During growth		Pulse	0.4	l	@	$24	$9.60	
	During growth		Ampligo	0.1	l	@	$412	$41.20	
	During growth		Pulse	0.4	l	@	$36.52	$14.61	
	During growth	Application	Contract sprayer	1		@	$24	$24.00	
TOTAL COST per hectare									**$993**

Appendix 3: Fodder beet direct costs

Category	Date	Operation	Product	Rate	Unit			Cost/ha	Sub-total
Seed		Seed	DLF Troya	1	box	@	$363	$363.00	$363
Establishment		Herbicide	Glyphosphate	4	L	@	$5	$20.00	
		Insecticide	Lorsban	0.2	L	@	$21	$4.25	
		Herbicide	Pulse	0.1	L	@	$24	$2.41	
		Application	Contract sprayer	1		@	$24	$24.00	
		Cultivation	Plough (contractor)	1		@	$145	$145.00	
		Cultivation	Topdown	1		@	$95	$95.00	
		Drill	Precision drill	1		@	$160	$160	$451
Herbicide	Pre-emergence	Herbicide	Glyphosate 360	1.0	L	@	$5	$5.00	
	Pre-emergence	Herbicide	Norton	2.0	L	@	$25	$50.00	
	2 true leaf	Herbicide	Goltix Flo	1.00	L		$93	$73.00	
	2 true leaf	Herbicide	Betaneal Forte	0.75	L	@	$97	$10.00	
	2 true leaf	Herbicide	Norton	0.40	L	@	$25	$10.00	
	4 true leaf	Herbicide	Goltix Flo	1.50	L		$93	$140.00	
	4 true leaf	Herbicide	Betaneal Forte	1.00	L		$97	$97.00	
	4 true leaf	Herbicide	Norton	0.60	L		$25	$15.00	
	8 true leaf	Herbicide	Versatill Powerflo	0.25	L	@	$88	$22.00	
	8 true leaf		Gallant Ultra	0.125	L	@	$178	$22.00	
	8 true leaf		Uptake oil	1.00	L	@	$11	$11.00	
		Application	Contract sprayer	4		@	$24	$96.00	$551
Pesticide	Pre-emergence	Insecticide	Lorsban	0.20	L	@	$21	$4.25	
	2 true leaf	Insecticide	Lorsban	0.20	L	@	$21	$4.25	
	4 true leaf	Insecticide	Ampligo	0.10	L	@	$359	$36.00	
	8 true leaf	Insecticide	Attack	0.75	L	@	$36	$27.00	$72
Fertiliser		Soil test	Nutrient test	1		@	$45	$5.63	
		Fertiliser	Lime (cart and spread)	3000	kg	@	$0.05	$150.00	
		Fertiliser	DAP	100	kg	@	$0.79	$79.00	
		Fertiliser	Potassium chloride	300	kg	@	$0.72	$216.00	
		Fertiliser	Sodium chloride	200	kg	@	$0.20	$40.00	
		Fertiliser	Borate 46	20	kg	@	$1.59	$32.00	
		Fertiliser	Urea	90	kg	@	$0.46	$41.40	
		Fertiliser	Potassium chloride	100	kg	@	$0.72	$72.00	
		Fertiliser	Urea	90	kg	@	$0.46	$41.40	
		Fertiliser	Potassium chloride	100	kg	@	$0.72	$72.00	
		Fertiliser	Urea	90	kg	@	$0.46	$41.40	
		Fertiliser	Potassium chloride	100	kg	@	$0.72	$72.00	
		Application	Contract spreader	3		@	$12	$36.00	
		Fertiliser	Cartage	1.12	t	@	$15	$17.00	$916
TOTAL COST per hectare									**$2,352**

Chapter 1
Introduction

1.1 Overview

The New Zealand dairy industry has expanded and intensified significantly in the last two decades, generating an increased need for dairy support land (DSL). An increasing number of dairy farmers, particularly those in the South Island, choose to use all of their dairy farm as a milking platform (MP) and therefore rely on DSL to enhance the overall success of their whole dairy operation (SIDDC, 2008). In addition to wintering cows, DSL supports the MP by rearing replacement stock, producing supplementary feed, and carrying over empty cows.

Most dairy farmers prefer to own DSL rather than rely on third party grazier support services, primarily to maintain control of cow condition over winter (Richards, 2006), which directly influences the production potential of the herd in the subsequent milking season (Roche et al., 2009). However, there has been considerable debate in regard to the benefits of owning DSL and whether owned DSL is financially viable relative to other alternative grazing options such as third party graziers or leased DSL (Woodford, 2006; Richards, 2006). Further, recent nitrogen constraints imposed by some regional councils are likely to impede the financial viability and productivity of owned DSL. In particular, Variation 1 of the Canterbury Land and Water Regional Plan (LWRP) requires dairy support farmers in Selwyn Waihora to reduce the nitrogen losses on their farm 22% beyond good management practice (GMP) by 2022 (ECAN, 2015). Consequently, dairy farmers that own DSL within Selwyn Waihora are under significant pressure to implement a system that meets the nitrogen constraints while not undermining the performance of their farming business.

This research uses a case study approach to explore the environmental and economic sustainability of DSL in the context of the Selwyn Waihora catchment. This research focuses on exploring the implications of Variation 1 on the physical, environmental and financial performance of individual dairy support farms. Overall, the research aims to identify how farmers in the catchment can achieve the nitrogen limits in the most cost-effective manner.

1.2 Research objective and relevance for the dairy industry

The main objective of this research is to examine the implications of nitrogen reduction limits on different types of DSL in the Selwyn Waihora catchment. The physical and financial performance levels achieved by New Zealand dairy farms are widely known (DairyNZ & LIC, 2015). Further, in light of the National Policy Statement for Freshwater Management (NPSFM), many studies have focused on the nitrogen losses from pastoral dairy farming, and the current mitigations available for mitigating on-farm nitrogen losses and their respective cost-effectiveness (for example Kaye-Blake et al., 2014; Smeaton, Cox, Kerr & Dynes, 2011; Vibart et al., 2015; Vogeler et al., 2014). Regional councils and industry good bodies, such as DairyNZ[1], have quantified the financial implications of regional environmental policies on dairy farms (DairyNZ Economics Group, 2015).

However, few in-depth investigations have explored DSL in Canterbury, particularly in regard to the financial feasibility, physical performance levels, and nitrogen leaching rates achieved through different DSL management operations. In the past focus has been placed on using a case study approach to gain insight into the management operations and profitability levels inherent in dairy support ownership in Canterbury (Richards, 2006). Bennett (2009) also broadly explored factors influencing the sustainability of DSL in Canterbury. These case studies however, were undertaken prior to the implementation of the initial NPSFM in 2011 (revised in 2014) and therefore lack consideration of the implications of farmers having to meet nitrogen loss targets on their DSL.

Research to date has largely excluded consideration of the implications of nitrogen policies on dairy support farmers. This exclusion is due to the absence of robust, accessible data from applied research and industry good bodies (such as DairyNZ), partly due to lack of distinction between DSL and other farm enterprises in terms of land use, with many properties being inherently interchangeable. In addition, most of the industry focus is on the MP, as that is where most of the profit and performance is measured. Variation 1 has heightened the need for sustainable management of DSL in the Selwyn Waihora catchment, and could result in many physical, financial and environmental changes. Further, farmers

[1] DairyNZ is the industry good organisation for New Zealand dairy farmers, which, among other things, develops applied research and collects data in response to current industry needs.

need to be able to understand how to meet their nitrogen constraints in the most cost-effective manner, to ensure their DSL meets the purposes it was purchased for.

The results from this research will assist DSL farmers in making informed decisions when considering how to mitigate their on-farm nitrogen losses. This will be valuable to the New Zealand dairy industry, as farmers are challenged to farm within environmental limits while not undermining their economic performance. This research will also contribute to the literature by complementing the few studies that consider the impact of environmental regulations on the cash operating profit of DSL, which will be of benefit to the regional councils that are yet to implement on-farm nitrogen discharge limits under the NPSFM. Finally, this research will also highlight areas where future research would be beneficial to support the sustainability of DSL.

1.3 Research questions

1. What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?
2. What are the current management practices used on DSL in Selwyn Waihora?
3. How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?
4. How will Variation 1 impact the future physical, environmental and economic performance of owned DSL?
5. How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

1.4 Research approach

A case study approach was chosen for this research, to explore the implications of Variation 1 in context of the conditions and constraints unique to each farming system. Four dairy farmers that own DSL in the Selwyn Waihora catchment in Canterbury were interviewed to provide data for subsequent analysis. Data was sought on the physical, financial and environmental levels currently achieved by DSL, as well as qualitative information pertaining to DSL ownership and the farmers preferred nitrogen mitigation strategy. Farm systems modelling was then undertaken to analyse the implications of reducing nitrogen losses on the four DSL farms. Overseer™ (6.2.3) was used to model the impact of mitigation strategies

Chapter 2

Background

2.1 The Selwyn Waihora Case Study

The Selwyn Waihora catchment is located in central Canterbury in the South Island, New Zealand. The geographic area covered by the Selwyn Waihora sub-region in the Canterbury Land and Water Regional Plan (LWRP)[2] is hydrologically bounded by the Waimakariri and Rakaia Rivers, and encompasses the catchment that flows east into Te Waihora (figure 1). This includes the foothill sub-catchment of the Waikirikiri/Selwyn River and its tributaries, the plains between the Rakaia and Waimakariri Rivers, part of the Halswell River/Huritini catchment, lowland spring-fed streams, and several ephemeral Banks Peninsula streams that flow into Te Waihora (ECAN, 2015). Te Waihora, also known as Lake Ellesmere, is a highly modified brackish lake which discharges into the South Pacific Ocean. It is New Zealand's fifth largest lake, with an approximate area of 20,000 hectares, and an average depth of 1.4 metres (Hughey & Taylor, 2009).

Material removed due to copright compliance

Figure 1: Map of the Selwyn Waihora sub-region zone. (ECAN, 2015, p. 196).

[2] The Selwyn Te Waihora sub-region in the LWRP does not apply to the entire Selwyn Waihora Water Management Zone in the Canterbury Water Management Strategy, as it excludes the alpine boundary in the north-west (the headwaters of the Waimakariri River and part of the headwaters of the Rakaia River, including Lake Coleridge).

Typical to the wider Canterbury region, irrigation is a significant feature of the Selwyn Waihora catchment. Irrigation abstraction has increased steadily over the last few decades (ECAN, 2012), enhancing agriculture productivity and economic growth (Harris Consulting, 2014). Approximately 105,000 hectares (or 49%) of the catchment's agriculture land is currently irrigated, sourced primarily from groundwater (ECAN, 2014). In addition, Central Plains Water Limited (CPW) has consent for irrigation development in the upper catchment. The scheme will use alpine surface water to irrigate 30,000 hectares of dryland (new irrigation) and replace groundwater takes on 30,000 hectares of existing irrigated land in the command area. Full development of the CPW irrigation scheme is expected to be complete by September 2018 (CPW, 2013). The Zone Committee Solutions package[4] assumes that new irrigation provided by CPW will convert dryland land uses to dairy (40%), arable (40%), sheep and beef (13%) and dairy support (7%) (Canterbury Water, 2013). However, fluctuating global milk prices have made this economic development appear risky, suggesting that the level of CPW uptake from dairy farmers may be revised downwards (Eppel, 2015).

2.2 Dairy farming in the Selwyn Waihora catchment

The Selwyn Waihora catchment, like the wider Canterbury region, has experienced an expansion in dairying in recent years (ECAN, 2014). This is supported by lower land prices relative to other regions, irrigation development, the adoption of new technologies, and the reduced returns from traditional pastoral farming systems (Dynes, Burggraaf, Goulter, & Dalley, 2010; Pangborn & Woodford, 2011). Since the 1990s, dairying land use and dairy cow numbers have experienced the largest overall change and increase in the Selwyn District, relative to other agriculture land uses and livestock numbers (Mactier, 2011).

Figure 4 shows the change in total cows, hectares and milksolids between 1996-97 season and 2014-15 season, according to the NZ Dairy Statistics (DairyNZ & LIC, 2015). This indicates a linear annual growth rate of 7% for total cows in Selwyn, 6% for total effective hectares and 9% for total milksolids. Figure 5 shows the change in milksolids per effective

[4] Following extensive consultation and collaboration with stakeholders, the Selwyn Waihora Zone Committee prepared the Selwyn Waihora ZIP Addendum in 2013, which recommends a water management solutions package.

2.2.1 Dairy support farms in the Selwyn Waihora catchment

The expansion and intensification of dairy farming in Selwyn Waihora has increased the requirement for DSL; to support the MP by wintering cows, grazing replacements and growing supplements (SIDDC, 2008; Dynes et al., 2010; Peel, 2013).

Despite its significance as an integral component of the overall dairy operation, there is little consensus surrounding the location and total area of DSL in the Selwyn District. In terms of land use, this is largely due to the lack of distinction between dairy support and other farm enterprises, with many properties being inherently interchangeable, as well as the lack of robust AgriBase GIS information (Ford, 2014). Lilburne (2014) and Harris Consulting (2014) estimated that there was 21,853 and 24,974 hectares of DSL in the Selwyn Waihora zone in 2014 respectively. Harris Consulting (2014) assumes about half this land is irrigated and the ratio of DSL to dairy is 0.55. Lilburne (2014) expects there are 243 dairy support farms, of which 82% (18,000 hectares) is integrated into sheep and beef farms.

2.3 Water quality in the Selwyn Waihora catchment

Under the NPSFM ECAN is required to set water limits that will maintain and improve freshwater values (MFE, 2014). This research focuses on the implications of the water quality limits set by ECAN in the Selwyn Waihora sub-regional section of the LWRP, particularly the physical and financial impacts of reducing nitrogen leaching per hectare on dairy support farms. While it does not attempt to take a position on freshwater quality in the Selwyn Waihora catchment, it is imperative farmers recognise the current state of freshwater bodies in their catchment, as this forms the basis of the limits in Variation 1.

Water quality in New Zealand catchments has generally declined due to agriculture intensification (Hamill & McBride, 2003; Ballantine & Davies-Colley, 2009; Monaghan et al., 2007), and Selwyn Waihora is no exception (Golder Associates, 2011; Hanson, 2014). Most of the lowland stream monitoring sites in the catchment do not meet water quality objectives set in the LWRP for biodiversity protection (Hanson, 2014). Two downstream sites of the Selwyn River (Coes Ford and Upper Huts) had faecal contamination at levels unsuitable for recreational use in the 2015-16 summer (ECAN, 2016), however it was not specified which land use this was from.

and does not exhibit the characteristics that are typical of severely degraded lakes (such as severe oxygen depletion and regular toxic cyanobacteria blooms) (Hughey et al., 2009). Poor water quality, however, fails Ngai Tahu values and expectations (Tipa, 2014).

The Selwyn Waihora catchment is over-allocated with respect to water quality, as it is currently not achieving all its freshwater objectives. Further, it can take considerable time for land use nitrogen loads to resurface in lowland spring-fed streams via groundwater, and deposit into Te Waihora. With no further land use intensification in the catchment, the current load of total nitrogen entering Te Waihora in the next 10 to 20 years has been estimated to increase by 35%, as a result of the cumulative effects of past and current land use (Norton et al., 2014). Therefore, the Selwyn Waihora catchment is substantially over allocated in accordance with NPSFM, as water quality will get worse before it can get better. Under the NPSFM, ECAN are obligated to maintain or improve freshwater resources. The regulatory framework to achieve this, in particular Variation 1, is explained in the following section.

2.4 Selwyn Waihora catchment nutrient management: Variation 1

In the last decade, water governance, planning and management have shifted significantly to address the popular concern and critical issues surrounding freshwater management in Canterbury and New Zealand (Duncan, 2014a). Under the Resource Management Act (RMA) (1991), the central government passed the NPSFM in 2011, which was later revised in 2014 (MFE, 2014). The NPSFM provides the overarching framework for freshwater management in New Zealand, and places regulatory obligations on regional councils to manage their region's water resources in an "integrated and sustainable way, while providing for economic growth within set water quantity and quality limits" (MFE, 2014, p.3).

The Canterbury Water Management Strategy (CWMS) which was launched in 2009, prior to the NPSFM, also sought to set water quality limits. This was the response following recognition that a shift was needed from 'effects-based' management of individual consents (adopted under the RMA) to integrated, collaborative management based on the management of cumulative effects of land-use intensification and water abstraction within water management zones (Jenkins, 2011). The CWMS established ten water governance bodies known as Zone Committees across the region. The Zone Committees are charged

2.4.1 Farming enterprises

Under Variation 1, farming enterprises can be established in which all non-connected parcels of land owned by one entity are grouped into a single land entity for the purposes of nutrient management. Reductions in nitrogen losses will also be required by 2022 according to the weighted average of the nitrogen reductions required from the particular farm activities used in the enterprises. For instance, an enterprise with 50 hectares of dairy land and 50 hectares of DSL will be required to reduce losses by 26%, as this is the average reduction required (dairy and dairy support activities must reduce losses by 30% and 22% respectively under Variation 1).

2.4.2 Irrigation scheme: Central Plains Water Limited

Nitrogen losses from dryland farms converting to irrigation supplied by CPW after the 1st January 2015 are to be accounted for by the CPW scheme, whereby the scheme is responsible for the administration of nitrogen discharge consents from the shareholders, as well as management of FEP implementation, audits and annual reporting to ECAN. Under Variation 1, CPW has been allocated 979 tonnes of nitrogen to distribute among their shareholders at their discretion based on an assessment of the difference between the dryland nitrogen baseline for their farming system and the nitrogen loss model for the proposed farming system within the limits of GMP. CPW is also required to limit initial nitrogen losses from these properties to GMP via farm management plans.

Chapter 3

Literature Review

3.1 Introduction

The purpose of this literature review is to evaluate the research that has been conducted on DSL systems in Canterbury, particularly in regard to the nitrogen leaching on DSL and the costs of mitigation. This review will highlight research gaps and where this research project can contribute to the current body of literature.

In addition to peer reviewed literature this review analyses a range of articles that can be classed as ‘popular’ literature, appearing in farmer conference proceedings and government documents; non-peer reviewed text which is often opinionated and subjective. However, the exploratory nature of this research means that popular literature is both important and necessary in providing information on current dairy support systems within the Selwyn Waihora catchment.

3.2 Dairy support farm systems in Canterbury

The majority of dairy farmers in Canterbury operate with a MP structure, essentially using their dairy farm as an intensive MP to achieve high stocking rates and high productivity over the milking season (Hockings, 2002; Peel, 2013). In the South Island, this strategy has been found to be more profitable than wintering cows on the MP, which results in lower pasture covers during the milking season and therefore a smaller herd (Cottier, 2000; Davis, 2005; Hockings, 2002; de Wolde, 2006). Further, some Canterbury farmers face a period over winter where heavy soils become waterlogged increasing the potential for pugging (i.e. damage to soil physical properties), resulting in declines in subsequent pasture production (Singleton & Addison, 1999). Therefore, in order to protect the production potential of their MP, many Canterbury dairy farmers are reliant on DSL; land that provides support to the MP by wintering cows, growing supplementary feed and raising young stock. Further, as dairy farmers strive to increase their productivity, the reliance and demand for dairy support services is likely to become greater. However, anecdotal evidence suggests the latest milk price downturn has resulted in a reduction in heifer replacement rates, an increase in farmers growing winter feed on the MP, and a decrease in supplementary feed use (Journeaux & Savage, 2016). This suggests that in low payout conditions, farmers are willing to sacrifice milk production in order to reduce operating expenditure.

Dairy support land can be utilised by the dairy farmer for a number of different purposes. Research on owned dairy support blocks in Canterbury found that although wintering non-lactating cows and supplying supplements to the MP were generally the most important management practices, many diverse complementary enterprises existed which contributed to the profitability of the system (Richards, 2006; Peel, 2013). These enterprises included heifer grazing, dairy beef rearing and fattening, and cash cropping. Likewise, Bennett (2009) and Dalley, Wilson, Edwards and Judson (2008) observed that operations on DSL are very diverse, however their primary use was wintering cows on forage crops. Overall, the relative scale of the DSL to the MP (Richards, 2006), the degree of feed deficiency on the MP (Dalley et al., 2008), and the capabilities of management and the land being farmed (Bennett, 2009), were the key determinants of the range and extent of enterprises that the land supported.

There are various forms of DSL systems, including owned or leased support blocks separate to the defined MP (either as adjacent or separate blocks) or land farmed by a third party grazier. In terms of the latter option, the integration of DSL into other farming operations (particularly arable) has been significant in Selwyn Waihora (ECAN, 2014; The Agribusiness Group, 2012) and the wider Canterbury region (Dynes et al., 2010; Peel, 2013). The land use on these properties can be dynamic and is strongly dictated by the relative profitability and price margins of the various operations. In particular, grazier payments are strongly determined by the supply and demand of third party grazing for replacement stock and cow wintering (Postiglione, 2013). This research does not analyse these third party graziers and their integrated, diverse farming systems, and instead focuses on owned DSL.

3.2.1 Reasons for dairy support land purchase

Winter management of dry pregnant cows is integral to the success of the overall dairy farm system, as the body condition score (BCS) of cows at calving significantly impacts milk production, reproduction potential, and animal welfare in the following season (Roche et al., 2009). Quality replacement heifers are also fundamental to enhance the future performance of the MP. Consequently, the strongest motivator for farmers purchasing DSL is to achieve direct control of feed supply and the condition of livestock in the overall dairy system (Bennett, 2013; Davis, 2005; O'Connor, 2003; Postiglione, 2013; Richards, 2006). Bennett (2009) found that larger dairy farm systems in particular are more likely to purchase DSL in attempt to control external risk factors. Substandard experiences (for example growth targets not met and price volatility) with third party graziers often result in farmers deciding the risk of sourcing feed externally is too high (Dalley et al., 2008). This emphasises that the reasons for DSL ownership often relate to risk management benefits and the self-sufficiency of the overall farm system, rather than the rofitability of the DSL block. In other words, *"Control (is) king, cash flow certainly (isn't)"* (Richards, 2006, p. 50).

Secondary factors influencing DSL purchase include:

- Economic opportunities: Capital gains (Dalley et al., 2008; Richards, 2006); ability to raise surplus livestock (for example replacements and bull beef) (Dalley et al., 2008; O'Conner, 2003).

- Non-economic factors: Increased variety of tasks and change from routine of milking cows; new challenge to the management team; DSL is a 'hobby' farm (Dalley et al., 2008; Richards, 2006)

3.2.2 Factors driving successful dairy support land farms

Few studies investigate the factors which contribute to the success of whole DSL farm system, as research is generally focused on the success factors of the wintering component of the DSL system (Dalley, Edwards, Rugoho, & Stevens, 2011; Dalley, 2014). However, Bennett (2009) explored the factors driving successful outcomes of 17 DSL farms across regions in the South Island. The study found that there were three main drivers to DSL success, as follows:

- Adequate resources: Machinery; irrigation water supply; component staff; technical knowledge (of cropping, soil management, supplement production and raising heifers).

- Planning: Growing feed; silage harvesting; forage crop preparation and establishment; feed budgeting; management of cows moving to and from MP.

- Timing and attention to detail in critical tasks: Pasture management; silage cutting; crop establishment; fertiliser and spray applications.

In terms of location from the MP, Bennett (2009) concluded that smaller, adjacent support blocks effectively complement dairy farming systems and allow cost savings, while larger blocks (particularly those detached from the MP) may require an independent management structure and dedicated management and resources (i.e. labour and machinery) to avoid poor decision making and strain on resources.

3.2.3 Wintering systems

The main issue encountered by dairy farmers in terms of wintering their cows, particularly in the South Island, is the inability to grow sufficient pasture during winter to meet the energy requirements of the herd in late gestation (Dalley, 2011). Subsequently, *in situ* grazing of forage crops over winter off the MP is a common practice in the South Island (Dalley, 2011; Pinxterhuis et al., 2013). However, off-paddock structures such as wintering pad systems are increasingly advocated as an alternative wintering system to mitigate the adverse environmental effects associated with wintering cows (Beukes et al., 2011). In addition, case study research (Bennett, 2009; Richards, 2006) indicates that a number of South Island dairy farmers would prefer a pastoral wintering system, given their higher perceived performance in terms of milk production and BCS (Pangborn & Gibbs, 2009; Rugoho, 2013). However, this is a relatively uncommon option for South Island dairy farmers (Pinxterhuis et al., 2013), given the climatic conditions constraining winter pasture growth (Dalley, 2011).

3.2.4 Forage crop wintering systems

A typical DSL block in Canterbury consists of a dairy wintering system on forage crop (SIDDC, 2008; Richards, 2006), reflecting the crops ability to yield large tonnes of high quality forage on a relatively small area with less deterioration in nutritive quality relative to perennial ryegrass (Brown, Maley, & Wilson, 2007; de Ruiter et al., 2007; Judson & Edwards, 2008; Nichol, Westwood, Dumbleton, & Amyes, 2003). In current feeding regimes, the crops are generally break fed, using temporary electric fencing to divide the paddock into daily

3.3 Nitrogen leaching

3.3.1 The nitrogen cycle

Nitrogen is an essential element for plant growth and biological function (Di & Cameron, 2002a; Hatch, Goulding, & Murphy, 2002), however excess nitrates in freshwater bodies have the ability to degrade water quality (Di & Cameron, 2002a; McLaren & Cameron, 1996; PCE, 2013). Figure 7 illustrates a simplified nitrogen cycle on a dairy farm; the transfer of nitrogen from one form to another within the soil-plant-animal-atmosphere system.

Material removed due to copright compliance

Figure 7: Simplified nitrogen cycle. (DairyNZ, 2013, p. 5)

In legume-based pastures and crops on dairy farms, biological fixation is an important source of plant available nitrogen (Di & Cameron, 2002a). Other sources of nitrogen include nitrogen containing fertilisers (de Klein, Monoghan, Ledgard, & Shepherd, 2010; Ledgard, Penno, & Sprosen, 1999) and imported supplements (DairyNZ, 2013a).

Within the cycle, nitrogen is converted to different forms that dictate the availability of nitrogen to plants and the transfer pathways of nitrogen. The amount of nitrogen cycling in a dairy system is dependent on several factors, with ingestion and deposition of nitrogen by the cow being a central component of the nitrogen cycle (Christensen, 2013; Moir, Cameron, Di, & Fertsak, 2011). Urinary nitrogen is largely in the form of urea, which is mineralised to plant available forms of nitrogen - ammonium (NH_4^+) and nitrate (NO^{3-}).

As seen in figure 8, not all of the nitrogen applied or fixed into the soil is assimilated by plants; a large proportion is incorporated into soil organic matter, or removed from the farm system as product, lost to the atmosphere, or lost to water. Nitrogen use efficiency[5] has been estimated to be between 25 to 50% at the farm level and around 15% for the individual cow (Ledgard et al., 1999), thus there are significant levels of excess nitrogen throughout the farm system which can be lost to the environment. The majority of nitrogen that is lost to water through surface runoff or subsurface drainage (leaching) is in the form of nitrate (NO_3^-) due to the highly soluble nature of the nitrate ions (Di & Cameron, 2002a; McLaren & Cameron, 1996).

3.3.2 Factors influencing nitrogen leaching on dairy support land

Nitrogen leaching occurs when there is an accumulation of nitrogen in the soil profile that coincides or follows a period of high drainage (Di & Cameron, 2002a). Both nitrate ions and soil particles are negatively charged, due to the same charges repelling one another, nitrate is not retained by the soils, and is subsequently prone to leaching during periods of high drainage (Di & Cameron, 2002a). Therefore, the amount of nitrate accumulated in the soil above the amount required for plant uptake, and drainage volume, are the two fundamental determinants of the amount of nitrate leached from the plant root zone (Cameron, Di, & Moir, 2013; Di & Cameron, 2002a).

The main factors affecting the level of nitrogen leaching losses are climatic season, soil properties and land use (Di and Cameron, 2002a). Typically, the primary driver of nitrogen leaching on dairy farms is urine deposition from grazing animals (DairyNZ, 2013a; de Klein et al., 2010; Di & Cameron, 2002a; Ledgard & Mennerr, 2005; Sharpley & Syers, 1979). In addition, forage crop wintering systems contribute to a disproportionately high amount of the total nitrogen leaching losses in dairy systems (Chrystal, Monaghan, Dalley, & Styles,

[5] Nitrogen use efficiency (NCE) describes the percentage of nitrogen inputs that are converted to nitrogen in saleable product (i.e. milk, meat) (nitrogen outputs) (DairyNZ, 2013).

3.3.3 Nitrogen mitigation

A suite of mitigation options to reduce nitrogen leaching losses from intensively grazed pastoral systems in New Zealand have been reviewed by Menneer et al. (2004), Monoghan et al. (2007), de Klein et al. (2010), Vibart et al. (2015), and Howarth and Journeaux (2016). However, Perrin Ag (2015) notes that very few studies have reported on the cost and effectiveness of mitigating nitrogen losses from the overall dairy support farm system. Mitigation of nitrogen leaching typically focus on three main options: reducing nitrogen inputs; more efficient utilisation of nitrogen within the farm system; or capturing or re-using nitrogen before it enters waterbodies (de Klein et al., 2010). These options are likely to involve changes in land management practices, improvements in farm production efficiency, reductions in land use intensity, and/or land use change (Anastasiadis et al., 2012). Optimal abatement typically involves a combination of mitigation strategies (Doole, 2015). Understanding the effectiveness and cost of mitigation is integral to informed on-farm adoption of these strategies.

It is important to note that these mitigations will have differing effectiveness based on the farm they are applied on; there is no 'one size fits all' approach to mitigating nitrogen losses from farms, as these factors need to be considered on a farm specific and farm system basis (Howarth & Journeaux, 2016; Ledgard et al., 2006). In addition, natural biophysical factors such as soil drainage type, terrain and climatic conditions and natural waterbodies all influence the amount and type of nutrients lost, and significantly influence the effectiveness of nitrogen mitigation strategies (DairyNZ, 2013a).

The following mitigation strategies discussed in this section represent those applicable to DSL. The analysis excludes:

- Effluent management - this practice is unlikely to be undertaken on DSL, particularly those blocks detached from the MP.
- Alteration of stock classes and land use change - as this is not considered to fit the purposes of DSL.
- Culling livestock in autumn or improving cow genetics - as this will largely occur on the MP.

efficient irrigation type or VRI is a significant capital investment and may help mitigate nitrogen leaching if irrigation was previously being used inefficiently.

Stock exclusion from waterways and riparian buffer zones

Fencing waterways is widely promoted as GMP to reduce the direct deposition of urinary nitrogen into waterways (DairyNZ, 2015; ECAN, 2014). Riparian planting, grass filter strips and wetlands generally provide a low benefit mitigation option for nitrogen leaching (Monaghan, 2014). Soluble nutrients, such as nitrates, are removed via microbial denitrification augmented by plant uptake and accretion in sediments (Parkyn, 2004). The effectiveness of these features for removing nitrogen varies considerably, depending on their ability to intercept and modify flow pathways (de Klein et al., 2010). Parkyn (2004) extensively reviews literature regarding the efficiency of riparian buffer zones, and concludes that most of the difference in studies of nutrient removal inefficiencies can be explained by site-specific variability in the characteristics of the buffer (width, type and maturity of vegetation) or in characteristics of the surrounding land (soil type, terrain). This study also suggests that a presence of a riparian buffer may be ineffectual at reducing soluable nutrient levels (other than through exclusion of stock) if the soils are well drained, thereby the soluble nutrients bypass the riparian buffer (Parkyn, 2004).

3.4 Farm systems modelling

Whole farm system theory is a holistic study on the various components contributing to the farm system as a whole. This approach emphasises the complex interactions between various elements of the biological farm system. An adjustment to one component may change the overall physical, financial and environmental performance of the farm system. The purpose of farm systems modelling is to examine how a change to one component of the system may impact the rest of the system, for example nitrogen reductions.

The objective of the farm systems modelling used in this research is to construct abatement cost curves; to define the financial cost of achieving a given level of nitrogen loss mitigation in a given context, in this case on farm (Doole, 2012). Abatement cost curves are extensively used because of their clear and concise explanation of both abatement and cost dimensions in a graphical framework (Radermacher, Riege-Wcislo, & Heinze, 1999). For the purposes of this research, economic and nitrogen loss changes are required to create an abatement curve, and a biophysical model is integral to ensure feed supply and demand is balanced at each point on the abatement curve (Muller, 2015). Currently, there is not a model which incorporates a biophysical farm system, nutrient losses and the economic performance of a farm. However, it is worth noting that the alignment and integration of Farmax and Overseer is a high priority for both companies (McEwen, 2015; Overseer, 2016). Many consultants and researchers throughout New Zealand have used both Overseer and Farmax to create cost abatement curves for farmers, regional councils, industry bodies, and research institutions (Vogeler et al., 2014). With respect to nitrogen regulations, this modelling approach is of value to help inform regional councils of the on-farm implications of various proposed policy and allocation options, as required by section 32 of the RMA.

3.4.1 OVERSEER™ nutrient modelling

Overseer™ is an agriculture management support tool that examines the impact of nutrient use and the flow of nutrients within a system, as well as greenhouse gas emissions, to optimise production and environmental outcomes (Selbie et al., 2013). The model uses a budgeting approach that measures nutrient inputs, transfers and outputs based on the information specific to an individual farm (Cichota & Snow, 2009; Wheeler et al., 2003; 2006). While the initial purpose of Overseer was to support fertiliser and nutrient management on pastoral farms, Overseer is being increasingly used to implement regional policy and regulations in relation to nutrient losses from agriculture (Cichota & Snow, 2009; Williams et al., 2013). For instance, nutrient limits within the LWRP and Variation 1 are set on the basis of Overseer (ECAN, 2015). For policy purposes, the reason for using a farm systems modelling approach is that direct measurement of nitrogen loss is impractical, costly and time consuming, given the scale and variability of farm systems (Addiscott, 1995; Duncan, 2014b; Shepherd et al., 2013). Overseer model is generally regarded as the most accurate tool for estimating nutrient losses across the diversity and complexity of farming systems in New Zealand (Doole, 2012). Matthew, Horne and Baker (2010, p.292) described Overseer as the “software of choice for predicting nitrogen leaching losses” for the dairy industry, farm consultants and many regional authorities. By quantifying nutrient losses at the farm level, Overseer allows regulators to adopt effects-based (i.e. output based) policy and regulations rather than rules based on input controls, which are inherently more inefficient with respect to their impact on farm productivity (Journeaux, 2016; Murray et al., 2016). Overseer is extensively used to evaluate the effectiveness of different mitigation practices (Journeaux, 2016; Shepherd, et al., 2013; Wheeler, Ledgard, & Monaghan, 2007).

Empirical relationships, existing farm information and internal databases are used in the Overseer to estimate nutrient inputs and outputs, and in turn calculate nutrient losses at the block and farm scale (Ledgard et al., 1999; Shepherd et al., 2013). Validation has shown Overseer to provide a reasonably accurate representation of nitrogen leaching loads of New Zealand farming systems (Parfitt, Mackay, Ross, & Budding, 2010; Ledgard et al., 2006; Wheeler, van der Weeden, & Shepherd, 2010). However, there is less certainty about the use of Overseer in regards to phosphorus (Gray, Wheeler, McDowell, & Watkins, 2016) as well as the nitrogen lost from arable crop rotations (FAR, 2013) and winter fodder crops (Farrell, 2015). Further, the use of Overseer for regulator compliance is recommended to be approached with caution (Cichota & Snow, 2009). Models that are continually evolving, such as Overseer, are generally better at describing relative changes, as opposed to providing the absolute value of leaching; thus it is recommended that policy emphasises the relative changes rather than the absolute output (Cichota & Snow, 2009).

The key assumptions underpinning the Overseer model are that: the system is in quasi-equilibrium (inputs and farm management practices commensurate with farm productivity); it uses long-term annual averages (i.e. the model assumes a “steady state”); the user supplies actual and reasonable inputs; and many GMPs have been implemented on the farm (Shepherd et al., 2013). Overseer also assumes that the farm is biologically feasible, for example, nutrient mitigation scenarios include changes in farm productivity (Wheeler et al., 2007). Therefore, Overseer is best used in conjunction with other models, to ensure the various mitigations applied are biologically feasible. Despite the concerns regarding the assumptions and the accuracy Overseer, it is considered the best tool available and will continue to be mandatory for the regulation of nitrogen leaching on Canterbury farms.

3.4.2 FARMAX® Professional

Farmax® Pro is a decision support software designed to assist the management of New Zealand farm systems. The farm-scale simulation model is a whole-farm decision support model that uses monthly estimates of pasture growth, farm and stock information to determine the outcomes of managerial decisions on production and financial performance (Bryant et al., 2010). Farm systems and economics models, such as Farmax, ensure a biologically feasible scenario is being represented and allow users to evaluate the financial implications of alternative farm systems and management changes. Energy intake is a key foundation of the model, therefore the pasture covers predicted from the balance of whole-farm feed supply and demand must be biologically feasible at all times (White, Snow, & King, 2010)

Farmax is a useful software to model an existing farm system and the potential impacts of different nutrient mitigations on profitability (Allen, 2012). The model has been widely used by consultants and industry bodies to create nitrogen abatement cost curves for pastoral farming in New Zealand, especially in conjunction with Overseer (for example DairyNZ Economic Group, 2015; Kaye-Blake et al., 2014; Smeaton et al., 2011; Vibart et al., 2015; Vogeler et al., 2014). One of the limitations of Farmax is it does not account for interest rates and the capital costs of mitigations, for example the capital costs of a winter stand-off pad (Allen, 2012). Another limitation is Farmax is not an optimisation model; with simulation models (such as Farmax) the definition of optimal resource use requires the user to iterate their way to an optimal solution, which is time consuming and not always reliable (McCall, 2013)

3.5 The cost of nitrogen mitigation

In recent times, the financial impact and cost-effectiveness of on-farm nitrogen mitigations has been the subject of several New Zealand studies, particularly dairy farm systems. In light of the NPSFM consultants, researchers and industry bodies have modelled the impact of nitrogen policies on farm profitability, using Overseer and Farmax (for example DairyNZ Economics Group, 2015; DairyNZ, 2013b; Kaye-Blake et al., 2014; Perrin Ag, 2015; Smeaton et al., 2011; Vibart et al.,2015; Vogeler et al., 2014). These studies have consistently indicated that the relative change in nitrogen leaching and operating profit for any given mitigation is inherently different for each individual farm system. This section discusses the few studies that have focused on the cost of mitigating nitrogen from the overall dairy support system.

Overseer and financial modelling of nitrogen mitigation strategies was also undertaken on 18 farms representive of land use in the Selwyn Waihora catchment, including two irrigated dairy support farms on light soil types (The Agribusiness Group, 2012). Two mitigation strategies were considered for DSL – efficient irrigation scheduling and DCD use in May and August. Efficient irrigation scheduling showed the greatest (40%) reductions in nitrogen leaching, with a reduced net cash position and total equity. DCD use resulted in relatively small (3%) reductions in nitrogen leaching, operating surplus and net cash position, however this is currently not a mitigation option due to product specifications.

The above literature indicates that nitrogen mitigation, as required under Variation 1, are likely to have significant implications on the operating profit of DSL, however the extent is largely determined by the mitigations adopted, farm management practices, farmer preferences, biophysical factors (soil and climate), and the farm's nitrogen leaching relevant to the 15 kgN/ha/year threshold in Variation 1.

3.6 Summary of literature review

Dairy support is an integral component of dairy operations, to support the MP by wintering cows, growing supplementary feed and raising young stock. The main reason of DSL ownership is to attain direct control of feed supply and livestock condition, which enhances the overall success of the total dairy operation. However, there is a lack of literature on the performance levels achieved by dairy support operations. Wintering on forage crops is a common practice on DSL in Canterbury. However, this practice can contribute to a disproportionately high amount of the total nitrogen leaching losses from the system, driven by high stocking rates, low plant nutrient uptake and high soil drainage. Regional authorities have developed, or are developing regional plans to maintain or improve water quality in New Zealand. A key aspect of these plans is the implementation of nitrogen loss limits for agriculture land. Consequently, DSL farmers are under significant pressure to implement a system that meets the nitrogen constraints. The literature has identified a suite of options to reduce nitrogen leaching losses from intensively grazed pastoral systems. Many consultants and researchers throughout New Zealand have used farm system modelling to create cost abatement curves; to define the financial cost of achieving a given level of nitrogen loss mitigation on farm. However, research to date has largely excluded

Chapter 4
Methodology

4.1 Research approach

This research uses a multiple case study approach (Yin, 1984, 2013) to analyse the implications of mitigating nitrogen losses from DSL, in context of the conditions and constraints unique to each individual farming system. In contrast to using industry averages, or a survey, a case study approach allows for in-depth, holistic analysis, and encourages a diversity of rich information that is required to fulfil the purposes of this research.

4.2 Selection of the case studies

Four case study farmers were selected using purposive sampling. Patton (1987, p.52) described purposive sampling as selecting "information rich" cases which have insight to the research questions, while Turner (2010) suggests cases should be selected based on their willingness to openly share credible information. Further, in order to limit potential bias from the small number of cases and allow the "triangulation of subjects" (Myers & Newman, 2007, p.1) there should be maximum variation between cases (Perry, 1998; Eisenhardt & Graebner, 2007).

Selwyn Waihora catchment has a range of soil and rainfall types, as well as a variety of DSL systems. In obtaining information 'rich' case studies, a strong emphasis was placed on selecting dairy farmers that offered diversity in terms of catchment biophysical (soil type) and farm system characteristics (crop and stock types, irrigation type, and absolute scale of the farm). This was considered important, given the small number of farmers studied and the heterogeneity inherent in DSL practices in Canterbury (Richards, 2006). Agriculture lecturers at Lincoln University acted as key informants in selecting case study participants according to the following criteria:

- The farmer owns a MP and DSL within the Selwyn Waihora catchment
- The farmer has access to robust physical, environmental and financial farm information

- The DSL farm provides diversity to other case studies, in terms of regional biophysical and management characteristics

4.3 Data collection

For the purposes of this research, data collection was in the form of personal interviews. Interviewing was considered the best method due to the quantity and detail of information required (Sekeran & Bougie, 2013). The interviews took place at the farmer's property, and generally lasted approximately two hours. Further questions and verifications were completed over the phone or email.

The interview guide (Appendix 1) provided structure to the interview and ensured that all required information was gathered. The first section of the interview was structured with quantitative questions pertaining to the management practices of the farm system and financial information. Farm data collected was based on the 2015-16 season and the wintering period in 2016. It was essential that the farm input data required for the Overseer and Farmax modelling was collected during this stage. The second section was semi-structured and focused on gathering in-depth, rich qualitative information, to understand the context of the farm system and the views of the farmer. The semi-structured section was designed to involve a balance of structure and flexibility, in which a combination of predetermined and improvised questions were asked. Unlike structured interviews, this method allows the researcher the flexibility to adapt probe questions based on the responses to their questions (Myers & Newman, 2007). The interviewer can therefore tailor their questions to the interview situation, taking advantage of the uniqueness of the specific case (Eisenhardt & Graebner, 2007). This mixed methods approach is a unique strength of case study research, as the collaboration of qualitative and quantitative data strengthens and validates the overall findings, and enables triangulated evidence (Yin, 1984; Eisenhardt, 1989).

The interview was recorded and brief notes were taken during the interview to aid the questioning. All the farmers provided farm maps to support the contextual understanding of their DSL farm, and how it was intergrated with the MP. In most cases, fertiliser budgets, soil tests and financial budgets were also provided. Audio recordings allowed the exact quoting of farmer responses. All information collected in the interviews was subsequently transcribed and used to create individual case study profiles. Each draft profile was sent to the individual farmer, to ensure the data was correctly intepreted.

4.4 Confidentiality Issues

Initial contact with farmers was by an email outlining the purpose and importance of the research. A subsequent phone call was used to ask the farmers if they were willing to participate and to arrange an interview. Provided the farmer agreed, a following email was sent to them including a research information sheet, consent form, and the interview guide. Confidentiality matters were addressed at the beginning of the interview, in which every farmer was assured that all disclosed information was confidential and would not be identifiable back to the individual farmers. The farmers were also asked for permission to audio record them. In order to ensure anonymity, each farmer was assigned a letter (for example Farmer C) to be used throughout this research. Although significant efforts have been made to avoid readers from identifying the farmers or the property, the author acknowledges that these privacy efforts may become void in circumstances where the reader is a close acquaintance with the particular farmer.

4.5 Quantitative research methods

4.5.1 Modelling process

Overseer (Version 6.2.3) and Farmax Professional (Version 7.1.0.31) were used simultaneously to create a nitrogen abatement curve[8] for each case study farm. Farmax ensured that the farm system created was biologically feasible (feed demand and supply are balanced) and allows the financial implications of mitigation to be analysed, while Overseer allowed the current farm systems nitrogen loss and the impact of mitigation strategies to be analysed (refer to section 3.5).

The Overseer files were created for each case study farm based on the best available farm data provided by the farmer for the 2015-16 season (including the 2016 wintering season). This data was smoothed to represent a reasonably average season as Overseer is designed

[8] Due to the few points produced for each farm from the modelling (i.e. base farm and 22% reduction scenario under Variation 1) the points have not been joined to form an abatement 'curve'. However, the dots still describe the theory behind abatement curves; the cost of achieving a given level of nitrogen loss mitigation, and therefore will be continued to be referred to as an abatement curve.

The mitigation modelling stopped when the reduction targets were achieved or if the farm got to the point where land was retired, as defined as having annual pasture surplus that was either sold or stored indefinitely. The results from these mitigation options were then analysed, particularly the impact on annual profit (measured by EBIT), production and nitrogen leaching. For the purposes of this project, operating profit and nitrogen loss are analysed on a per hectare per annum basis, to allow a consistent, comparative analysis between farms. In addition, Variation 1 requires a 22% reduction in nitrogen loss per hectare, therefore it is considered an appropriate indicator for this research. These points were used to create abatement curves; to estimate the impact of relative change between nitrogen leached and farm operating profit per hectare from the original base point for each case study farm.

4.5.2 Mitigation strategies

The mitigation strategies were chosen according to the following criteria:

- The mitigation is the most cost-effective method to reduce nitrogen leaching from a DSL farm system
- The mitigation is able to be incorporated into a DSL farm system in a practical manner, with the farmer maintaining the same level of skill
- The mitigation is recognised by the current Overseer model.

A review of the literature on nitrogen mitigation options (refer to section 3.3.3), discussions with experts and the case study farmers, as well as preliminary Farmax and Overseer modelling, acted as key information as to which mitigation options were selected. In particular, the chosen mitigations and process is broadly consistent with those employed by the DairyNZ Economics Group (2015) in their report which models the financial implications of reducing nitrogen loss on nine case study dairy farms within the South Coastal Canterbury Streams zone. While this study included only dairy farms, it was chosen over studies that focused on DSL as they used mitigations that were no longer available (DCD), required significant capital expenditure, or were beyond the constraints of Overseer. In addition to this, the DairyNZ Economics Group (2015) study presented mitigations that were clearly structured and broadly relatable to DSL. The author acknowledges that the chosen stocking rates were not reduced below the point where surplus pasture was produced, which infers land was not required for dairy support and could be retired.

4.5.3 Modelling assumptions

General modelling assumptions

A range of assumptions that were consistent across all farms underpinned the modelling, to ensure the farms were comparable. Firstly, the mitigation strategies that were considered the most cost-effective method to reduce nitrogen loss within the constraints of Overseer. However, it is acknowledged other mitigations, such as diverse pasture and riparian buffer zones, may be a more cost-effective method to reduce nitrogen, however they are not considered within the scope of this research as they cannot be modelled in the current version of Overseer.

The modelling was conducted under the assumption that farmers were operating at a point on a given production possibility frontier which did not shift, therefore the mitigations that would require improved skill and management capability were largely excluded. This assumption was considered important because significant changes in these variables are likely to require farmers to increase their skill level, which would require varying resources (time and money) according to the individual farmer, which are unable to be captured accurately within this modelling. Further, dramatic changes in the above variables are likely to disrupt the existing farm system. The farmer’s skill and management ability are held constant by providing for no livestock productivity gains from the baseline and constraining how much imported supplement (as a proportion of total feed offered per cow) could be altered from the base farm system. Arguably, incorporation of the stand-off pad would require a significant change in the farm system and farmer’s skill (Beukes et al., 2011; Journeaux, 2013), in terms of effluent management, animal welfare, supplementary feeding and labour, however this strategy was only employed in the ‘worst-case’ scenario when the de-intensification strategies were unable to meet the nitrogen targets. These changes were carefully considered when modelling the stand-off pad (see following section).

As aforementioned, the mitigation process was stopped if the farm got to the point where land was retired, as defined as having annual pasture surplus that was either sold or stored

Chapter 5

Results

5.1 Introduction

This chapter presents the case study profiles of the four farmers who participated in this research. The farmers were located in the Selwyn Waihora catchment, and owned a MP and DSL. Each farmer has been assigned a letter for confidentiality reasons.

Section 5.2 to 5.5 details the case study profiles, which will provide an overview of each farmer's total dairying operation, as well as the farmer's reasoning for purchasing the DSL block and the management operations of their existing dairy support system. The environmental performance of the current system is determined using Overseer (version 6.2.3). Following this, the environmental, physical and financial implications of a 22% reduction in nitrogen losses is analysed by using Overseer and Farmax modelling tools simultaneously. Section 5.6 summarises the findings from all the case studies farms and section 5.7 details the abatement cost of reducing nitrogen loss on each farm.

5.2 Case Study A

5.2.1 Overview

Farmer A's total dairying operation encompasses two irrigated dairy farms (334 total effective hectares), across which 1,170 cows were milked in the 2015-16 season (3.5 cows per hectare). The dairying operation also includes a small leased DSL block adjacent to one of the dairy farms, and 106.3 effective hectares of owned DSL located a small distance from the MPs. The focus of this case study is placed on the later DSL block, which consists of 80% of the enterprises total support. This DSL is hereafter referred to as the 'main DSL block'.

Fodder beet has been recently grown on both MPs (19 hectares total), on which all the cows are milked and transitioned on in May and almost half the cows are wintered. Fodder beet was incorporated into the MPs for a number of reasons; to eliminate the risk and *"hassle"* associated with third party graziers, save on silage and cows transport costs, utilise labour during winter, achieve better cow condition and contribute to the pasture renewal programme. During the wintering period, the remaining half of the herds cows are split between the two DSL blocks and are fed kale or fodder beet crops. The main DSL block is also used to supply baleage to both MPs and raise all the heifer replacements (9 month old calves to heavily pregnant heifers), while the other DSL block is used to graze all replacement calves (weaners to 9 months old). DSL has allowed the overall dairy system to be self-sufficient with its grazing, as well as partly self-sufficient with its supplements (approximately 20% of the MPs supplements consists of baleage imported from the DSL). Farmer A was "*really happy with how the (overall dairying) system worked"* and perceived it is "*an integrated system".*

5.2.2 Reasoning for purchase

Farmer A purchased the main DSL block in 2014 from a mixed sheep, beef and cropping farmer. The primary reason behind Farmer A's decision to purchase this DSL block was to gain greater control over the feed supplies necessary to support the MPs; to secure the grazing of young stock, winter a portion (13%) of the herd, and provide feed to be transferred to the MPs. Prior to the purchase, the farmer had substandard experiences (growth targets not met and price volatility) with third party graziers. Farmer A notes that although it is *"probably cheaper to use a grazier at current prices"* and the DSL *"has not saved any money (due to debt repayments)", "lots of volatility is taken away by… (grazing replacements and wintering cows) yourself"* and *"we have control".* Overall, the DSL purchase was perceived to be *"just another way of risk management".* Therefore, it is evident that the underlying reasons for the DSL purchase related to risk management and control, as opposed to optimising profitability.

The close proximity of this DSL block to nearby townships also offers potential for long-term housing investments, however this is considered a secondary reason for purchase. In addition, the DSL has *"better soils than the MPs",* which contributed to the purchase. Farmer A notes that nitrogen regulations (under Variation 1) restricts the DSL being converted into a MP in the future, and bull beef enterprises and potato cropping would result in less baleage production and potentially higher nitrogen leaching; therefore, DSL is currently seen as the lands best use.

5.2.3 Dairy support operation

The main DSL block is 106.3 effective hectares (110 total hectares) and is irrigated with centre pivot (54.3 hectares) and rotorainer irrigation (52 hectares) from September to April. There are three main soil types on the property, including Templeton silt loam, Barrhill silt loam and two siblings of Eyre silt loam. The farm supports the grazing needs of all the heifer replacements from both MPs (280 heifers), which arrive at the property in May each year and remain there until the end of June in their second winter. An additional 150 late calving cows are also on the farm from June, and are staggered back to the MP just before calving (79 average grazing days/cow).

A cropping rotation of pasture – fodder beet – barley and annual ryegrass (forage barley) – kale – barley and annual ryegrass – kale or fodder beet is grown on light soils under the areas irrigated by the rotorainer. Last year, 22.1 hectares of kale and 6.9 hectares of fodder beet were grown, which formed the basis of the wintering system. In addition, 18 hectares of forage barley was grown, which was harvested as cereal silage in November before being grazed as annual ryegrass by the stock. A total of 920 bales of baleage and 360 bales of cereal silage were produced and retained on the DSL, and an additional 290 baleage bales were sent to the MPs. Straw (20 tDM) was also imported. The majority of these supplements were fed during the wintering period. Nitrogen fertiliser is applied to the pasture area at approximately 160 kgN/ha/year. Based on measured crop yields, baleage harvested and the stock grazed, on average, 13,500 kgDM/ha/year is grown across the DSL block.

5.2.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 54.3 kgN/ha over the total farm area. Kale and fodder beet crops occupy 27% of the total effective area and leach 86% of the farms total nitrogen.

Forage crop and nitrogen fertiliser expenses decreased by 2.6% and 13.6% respectively. It is worth noting that this farm had a low EBIT to start with, therefore the absolute reduction is relatively small in absolute terms. However, this also meant that the high relative change (26.8% reduction) could leave the farm with very little EBIT left to pay interest, tax, capital improvements and repay debt and they are unlikely to be able to meet these financial obligations.

The stand-off pad mitigation resulted in the following changes:

- 100% of stock utilising the stand-off pad from May to August. The stock were grazed only on crop during this time, therefore the pasture blocks were unchanged.
- All supplements fed from May to August were fed on the stand-off pad, with a higher utilisation rate, therefore 20% less supplements were fed out during this period and 49 tDM of baleage and 8.2 tDM of cereal silage was sold.
- 6.3% reduction in nitrogen fertiliser use (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in an 8.4% reduction in nitrogen leaching and a 71.3% reduction in EBIT from the base. Total revenue increased by 2.5%, due to the increased sales of supplementary feed. Expenses were increased by 51%, largely due to the significant cost ($44,352) of the stand-off pad. Nitrogen fertiliser expenses decreased by 9.8% and wages increased by 9.8%. When the interest cost was included in addition to the operating expenses of the stand-off pad ($73,718 total), EBIT was reduced by 133%. This interest cost made the farm financially unviable.

5.3 Case Study B

5.3.1 Overview

Farmer B owns two MPs, milking a total of 1,530 cows on 387 effective hectares (4 cows per hectare). The farmer is a strong advocator of the resilience of pasture based systems which forms the basis of both his MPs. However, last season fodder beet was sown on the MPs and fed during late lactation in response to the low milk price.

The dairying operation also includes 160 effective hectares of DSL, located in close proximity to one of the MPs. The DSL is used to raise replacement heifers, and supply supplementary feed to the MPs. This block is usually unable to be wintered on due to its heavy, poorly drained soils, therefore the rising two year olds and cows are wintered *in-situ* on forage crops purchased as standing from a neighbouring farmer. Farmer B places great emphasis on maintaining optimal control of the feed supplies necessary to support the total dairying enterprise, which has been achieved through the DSL and wintering on standing crops. Due to this control, Farmer B is content that his total dairying operation is *"a very good system".*

5.3.2 Reasoning for purchase

Farmer B purchased 80 hectares of DSL in 2007 for grazing replacement calves. The block had been previously run as a beef fattening block. In 2013, another 80 hectare block of cropping land adjacent to the existing DSL block came up for sale and was purchased by Farmer B for replacement heifer grazing. The main driver behind these two purchases was attaining optimal control over the whole dairying operation. Farmer B describes the inability of third party graziers to grow heifers as a *"wicked problem experienced throughout the country". "they were coming back at 400-450 kgs…all I want to see is my stock fed well…I don't think they (the graziers) realise they have our next year's production in the palm of their hand".* It was therefore through frustration that the DSL was purchased, as it provided a means of control over the future productivity of the MPs. *"It was a no-brainer to buy the other block when it came up, it meant I could …graze my…heifers. You cannot afford to give someone control of your stock, simple as that".*

Farmer B believes that the DSL is beneficial to the overall dairying enterprise. Since the purchase, the condition of in-calf heifers returning to the MPs has improved significantly. "*Previously they were coming back at 400 to 450 (kgs), now they are coming back at almost 500 (kgs)".* In addition, herd tests have indicated that milk production has increased *"On average, each heifer's milk production is now 80% of the mixed age cows rather than 75%, just from the heifers being grown out properly"*. Flexibility when drying cows off was considered a secondary benefit of the DSL purchase.

5.3.3 Dairy support operation

Farm B is a 160 (effective) hectare DSL block and is fully irrigated with rotorainer irrigation from October to March. A large proportion (80%) of the property is artificially drained, as its soils are predominantly poorly drained. The farm is used exclusively for grazing all the replacement heifers from both MPs. Heifer calves arrive on the DSL block in December as weaners and are taken through to 21 months of age before returning to the MP at the end of May. The rising one year old heifers are typically wintered off the DSL to avoid soil pugging, however dry winter conditions have allowed the calves to be wintered in the last two years.

Last year, 6 hectares of fodder beet and 8 hectares of rape were grown primarily to winter the rising one year olds. In addition, 15 hectares of ryecorn was grown for heifer grazing during spring. Supplementary feed production included 250 hay bales, 200 baleage bales and 530 tDM of pasture silage, of which 100 baleage bales were retained and the rest was sent back to the MPs. No supplements were imported into the farm system. Nitrogen fertiliser was applied to the pasture area at approximately 160 kgN/ha/year, from August to March. Farmer B places a strong emphasis on high performing young grass to achieve the target growth rates of his replacement stock. Half the DSL was sown into new pasture two years ago when it was purchased, while just over 10% of the remaining DSL is regrassed each year.

5.3.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 18.4 kgN/ha over the total farm area. Crops represented 18% of the total farm area and were responsible for 57% of the farms total nitrogen losses. Fodder beet leached significantly higher concentrations of nitrogen relative to the other blocks, and was responsible for 40% of the farms total nitrogen leaching despite occupying only 4% of the farms area.

5.4 Case Study C

5.4.1 Overview

Farmer C manages a large scale dairying operation owned by his family business. The enterprise includes six MPs (2,420 total hectares) milking a total of 8,750 cows and three DSL blocks which are located approximately three kilometres from four of the MPs. The first DSL block (70 hectares) was recently purchased for calf grazing. The second block (72 hectares) is used for wintering cows and calf grazing, and the third block (65 hectares) is used for wintering cows and producing silage for the MPs. The focus of this analysis from hereafter is on the third DSL block, which provides the largest proportion of support to the MP relative to the other DSL blocks. Farmer C uses third party support services for some grazing and supplementary feed, however the DSL provides greater control. In addition, 30 hectares of fodder beet is grown on the MPs for wintering cows. Farmer C describes his dairying system as having *"good balance"*, due to his successful relationship with his third party grazier and his low exposure to the market in terms of feed supplies.

5.4.2 Reasoning for purchase

Farmer C purchased the DSL in 2002 from a dryland sheep farmer. Attaining more control over winter grazing and supplementary feed, as well as the close proximity to the MPs were the primary reasons for purchase. Prior to the purchase, all the cows were wintered on the MP. Farmer C notes that the current system is much more *"cost-effectiv*e", in which the DSL produces a larger amount of dry matter per hectare. The farmer is aware that if all the cows were wintered off using a third party grazier, the business would be *"heavily exposed to the market".* Secondary reasons for purchase include the benefit of land appreciation, the flexibility of sending cows on and off, and the opportunity to diversify the business (cash cropping).

5.4.3 Dairy support operation

Farm C is 63.1 effective hectares and is fully irrigated with two lateral irrigator runs from October to late March. Soils on the property are predominantly well drained, shallow stony loams. Farm D is used for wintering 1,350 dairy cows which arrive from the 1st June and are staggered leaving just before calving (58 average grazing days/cow).

In the last three years the farm has implemented an intensive, systematic cropping rotation of barley and annual ryegrass (forage barley) – fodder beet – barley and annual ryegrass – kale. This year, 13.7 hectares of kale and 15.4 hectares of fodder beet were grown for wintering cows. In addition, 30.9 hectares of barley and annual ryegrass was grown. This was harvested as cereal silage in December and sent back to the MPs for cow transitioning prior to calving. Another two cuts of silage were taken in late January and March for the MPs, before the pasture was shut up for *in-situ* winter grazing. Straw (115 tDM) was purchased to supplement the cows on the winter forage crops. Next year, Farmer C will grow peas as an additional income stream between the grazing of forage crops and sowing of barley and annual ryegrass. Timing, planning and attention to detail were key features of this case study.

5.4.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 38.7 kgN/ha over the total farm area. The fodder beet crop leached almost twice as much nitrogen per hectare relative to the other crops. Nitrogen leaching from the barley and annual ryegrass crop increased over four-fold if the crop was previously sown in fodder beet rather than kale.

Table 12: Summary of Overseer blocks and nitrogen leaching on Farm C

Block	**Hectares**	**Nitrogen leaching (kgN/ha/year)**
Kale	13.7	23.1
Fodder beet	15.4	80.5
Fodder beet – Barley and annual ryegrass	16.1	44.3
Kale – Barley and annual ryegrass	14.8	8.3
Pasture	3.1	14.2
Average nitrogen leached (kgN/ha/year)		**38.7**

The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 22%:

1. Fodder beet leached the most nitrogen on the basis of MJME/kgN (fodder beet: 4212 MJME/kgN; kale: 6856 MJME/kgN). Therefore, the fodder beet crop was reduced in steps of 5% and replaced with kale crop. In the end, the fodder beet crop

- 8.5% reduction in nitrogen fertiliser to crop (due to increased effluent applications from the effluent captured from the stand-off pad).

This resulted in a 14.9 % reduction in nitrogen leaching and a 55.7% reduction in EBIT from the base. Total revenue increased by 2.3% due to the additional supplementary feed sales. Expenses increase by 70.4% largely due to the significant cost of the stand-off pad ($115,493). Wages and conservation crop expenses increased by 20.2% and 30.1% respectively. The farm experienced a 116% reduction in EBIT when the cost of interest was added to the stand-off pad ($197,465).

5.5 Case Study D

5.5.1 Overview

Farmer D's overall farming enterprise includes four MPs (1,020 effective hectares) milking a total of 3,580 cows and two DSL blocks. The first DSL block (375 effective hectares) is located approximately 20 kilometres from the MPs and grazes all the replacement stock for the enterprise. The second block was purchased last year for the purposes of wintering all the enterprises cows and producing supplementary feed. The focus of this analysis is on the older, well established DSL block (375 effective hectares).

This farming operation places a great emphasis on having high levels of transparency between each individual enterprise. To attain this, each of the farms are treated as a standalone enterprise. All movements of feeds between the different farms, including labour transfers, as well as grazing, is fully priced and charged at the market rates. Farmer D is therefore able to accurately assess and evaluate the financial performance achieved by each farm, and ascertain how each contributes to the company as a whole.

5.5.2 Reasoning for purchase

Farmer D purchased this DSL in 2011 from a sheep and beef farmer. The primary reason for the purchase was to attain optimal control of the dairy systems replacement stock. Previously, Farmer D utilised third party graziers however purchasing a DSL block meant the farmer *"could only blame himself"* when it came to effectively achieving heifer growth rate targets. Overall the DSL provides better control, flexibility and management of growth rates. Farmer D notes that it would be very difficult to find a third party grazier who could provide grazing for over 3,300 heifers, and a benefit of the current system is having all the replacement stock in one location which is handy to the MPs. A secondary benefit of the DSL purchase is land appreciation. Farmer D notes the potential for the land to be used for housing developments or dairy farm conversion in the future. The future of the DSL will determined by a review in the near future.

5.5.3 Dairy support operation

Farm D is 375 effective hectares. The farm is fully irrigated by centre pivot irrigation from September to late April, using soil moisture tape monitoring for scheduling. Farm D is used exclusively for grazing all the replacement heifers for the dairying enterprise. Heifer calves (1,600) arrive on the farm as weaners in mid-December and are taken through to 22 months of age before leaving the DSL at the end of April as in-calf heifers. A small proportion (290) remain and are wintered through to the end of May before being sent back to the MPs. In addition, 70 bull calves are purchased in January and are taken through to November in the following year before being sent to the MPs for two months of mating and later sent to the works as rising three year olds. These bulls are used to mate the heifers on the DSL as rising two year olds. There is no feed interaction between this DSL block and the MPs.

A total of 10% of the effective farm area is used for winter forage cropping. Last year, 26 hectares of fodder beet and 10.5 hectares of kale was grown for heifer wintering purposes. Baleage is made during periods of pasture surplus – last year 230 tDM of baleage was produced and retained on the farm. The farm also imports 150 tDM of pasture silage. The majority of these supplements are fed in winter as a component of the fodder beet diet, however some supplements are fed in spring and autumn. Nitrogen fertiliser is applied as urea to pasture every month from August to March, totalling approximately 200 kg N/ha/year. Approximately 18% of the effective area is regrassed each year (30 hectares perennial ryegrass, 39.5 hectares annual ryegrass). Farmer D places a strong emphasis on achieving the target growth rates set for the replacement stock. A sophisticated weighing system is used regularly to weigh all stock and feed them accordingly. *"What drives the farm is (livestock) weight".*

5.5.4 Environmental and economic analysis

Modelling of the base scenario in Overseer estimated annual losses of 37.4 kgN/ha over the total farm area. Fodder beet leached significantly higher concentrations of nitrogen relative to the pasture and kale blocks, and was responsible for 37% of the farms total nitrogen leaching despite occupying only 7% of the farms area.

Table 13: Summary of Overseer blocks and nitrogen leaching on Farm D

Block	Hectares	Nitrogen leaching (kgN/ha/year)
Pasture	349.0	22.7
Kale	10.5*	116.0
Fodder beet	26.0	206.8
Average nitrogen leached (kgN/ha/year)		**37.4**

**This area rotates through the pasture block, therefore is not calculated in the total hectares*

The following iterative changes were made to the base model in order to achieve a nitrogen loss reduction of 22%:

1. Removal of fertiliser applications in March (25 kgN/ha).

2. A 1.6% (25 cow) reduction in rising two year olds from the 16th February to the 30th April to recover from the resultant pasture deficit.

3. Establish an oat cover crop in August following half of the kale crop (crop grazed prior to August) and all the fodder beet crop (23.5 hectares). The cover crop is harvested in late November as silage (7.5 tDM/ha) and perennial ryegrass is sown (consistent with the farms current rotation). All oats silage is sold off the farm.

4. Kale leached the most nitrogen relative to fodder beet on the basis of MJME/kgN (kale: 991 MJME/kgN; fodder beet: 1,237 MJME/kgN). Therefore, kale was reduced and replaced by fodder beet in steps and eventually was replaced by fodder beet (4.9 hectare increase in fodder beet) (keeping MJME/cow constant). The pasture area increased by 5.6 hectares as a result.

5. A 15% (4.6 hectare) reduction in fodder beet crop.

5.6 Summary of case studies

5.6.1 Base farm information

Category	Case Study			
	A	B	C	D
Dairy (MP)				
Number of MPs	2	2	6	4
Total effective hectares	334	387	2,420	1020
Total cows (peak milking)	1,170	1,530	8,750	3,600
Average stocking rate (cows/ha)	3.5	4.0	3.6	3.5
Average production (kgMS/cow)	1,627	1,677	1,423	1,569
Average production (kgMS/ha)	463	424	394	444
Dairy support land (DSL)				
Effective hectares	106.3	160	63.1	375
Ineffective hectares	3.7	0	0	14
Total hectares	110	160	63.1	389
Topography	Flat	Flat	Flat	Flat
Climate	593 mm/year rainfall 11.9 °C mean annual temperature 885 annual PET (mm)	609 mm/year rainfall 11.8°C mean annual temperature 910 annual PET (mm)	575mm/year rainfall 11.9°C mean annual temperature 897 annual PET (mm)	682 mm/year rainfall 11.8°C mean annual temperature 927 annual PET (mm)
Soil type and drainage	13% Templeton silt loam, well drained; 36% Barrhill sandy loam, well drained; 52% Eyre stony silt loam, well drained	76% Ayre deep clay, poorly drained; 10% Darnley silt loam, moderately, well drained; 14% Waimairi peat over silty loam, very poorly drained 80% artificially drained	100% Rakaia stony sandy loam, well drained	100% Lismore silt loam, well drained

5.6.2 Mitigation results summary

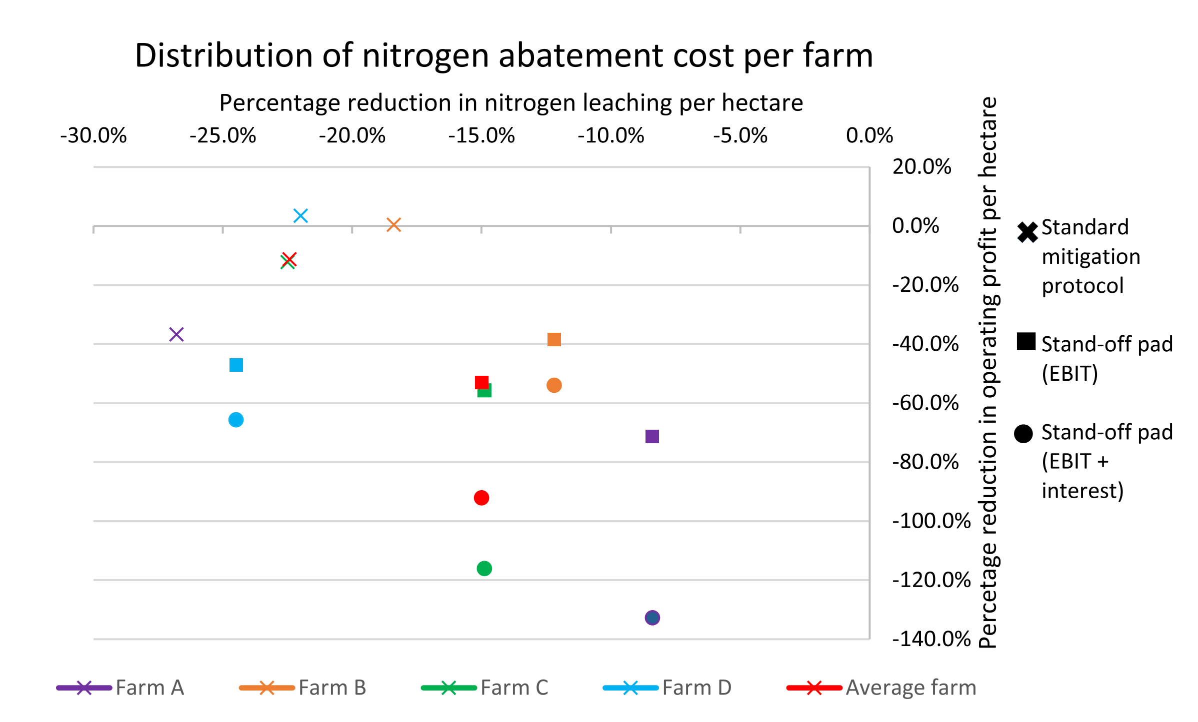

Figure 11: Distribution of nitrogen abatement cost per farm.

Table 14: The impact of the standarised nitrogen mitigation protocol on operating profit.

	Change in nitrogen leaching (%)	Change in EBIT (%)
Farm A	-26.8%	-36.7%
Farm B	-18.4%	0.4%
Farm C	-22.5%	-12.2%
Farm D	-22.0%	3.5%
Average	-22.4%	-11.3%

Table 15: The impact of the standoff pad on operating profit, and operating profit and interest.

	Change in nitrogen leaching (%)	Change in EBIT (%)	Change in EBIT + interest (%)
Farm A	-8.4%	-71.3%	-132.7%
Farm B	-12.2%	-38.5%	-54.0%
Farm C	-14.9%	-55.7%	-116.0%
Farm D	-24.5%	-47.0%	-65.7%
Average	-15.0%	-53.1%	-92.1%

Chapter 6

Discussion

6.1 Introduction

The objective of this research project was to understand the implications of nitrogen regulation on the performance of dairy support farms in the Selwyn Waihora catchment in Canterbury. The literature review in Chapter 3 identified a gap in the knowledge surrounding DSL in Canterbury, particularly in regard to the nitrogen leaching rates achieved through different DSL management operations and the implications of nitrogen constraints on DSL. This led to the research questions:

- What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?
- What are the current management practices used on DSL in Selwyn Waihora?
- How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?
- How will Variation 1 impact the future physical, environmental and economic performance of DSL?
- How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

The purpose of this chapter is to discuss the research findings in relation to the five research questions. Comparisons of the findings with literature were made where appropriate. Each research question has a concluding summary.

6.2 What are the reasons for dairy farmers purchasing DSL in Selwyn Waihora?

All study participants emphasised that achieving greater control over their overall dairy enterprise was the strongest motivator behind their DSL purchase. These farmers recognised DSL as being a means to gain direct control of the feed supply and the condition of livestock in the overall dairy system by wintering cows, growing supplementary feed and raising young stock. Throughout the interviews it became evident that the farmers were prepared to sacrifice profitability in order to attain this control. Farmer D was the only

Table 16: A comparsion in size and milk production between the case study farms and the average Selwyn District farm.

	Averages for the Selwyn District 2014-15 (DairyNZ & LIC, 2015)	**Average for the case studies in 2015-16 (milking platform only)***	**Range from the case studies***
Herd size (total number of cows)	738	919	563 – 1,444
Effective hectares (milking platform)	225	254	157 – 399
Stocking rate (cows/hectare)	3.28	3.6	3.4 – 3.9
Milksolid production (kgMS/cow)	411	436	421 – 483
Milksolid production (kgMS/hectare)	1,348	1,579	1,523 – 1,664

**All of the case study farmers owned more than one milking platform. Therefore, these figures are an 'average' milking platform across each case study farmer's total dairying operation.*

In general, all other factors stemming from the purchase were perceived as being secondary in importance, namely flexibility, land appreciation, the opportunity to diversify the business and invest in housing development. Farmer A and D were located close to townships and were aware of the growing demand for housing developments and the potential to capitalise on the investment opportunity.

6.2.1 Summary

Control of feed supply and livestock condition in the overall dairy system was the strongest motivator behind the case study farmers purchasing DSL. All other factors were perceived as secondary in importance, including flexibility, land appreciation, providing a diversified income stream and investment opportunities.

6.3 What are the current management practices used on DSL in Selwyn Waihora?

The DSL case study farms were predominantly used for cow wintering, grazing replacement heifers and producing supplementary feed for the MP. These case studies did not exhibit the diverse management practices defined by Richards (2006), Bennett (2009) and Dalley et al. (2008), for example none of the farmers sold supplements or grazed stock for external

Three of the study participants (Farmer A, B and C) used their DSL to export feed supplies for use on the milking platform. This 'milking feed' was used primarily to fill feed deficits in the autumn and for transitioning the cows prior to calving. Controlling the availability of this feed, its quality and its pricing, was cited by these farmers as the reason for this DSL and MP interaction. None of the farmers sold supplements to external parties, indicating the inherent feed synergies between the DSL and MPs. This interaction is because the blocks were owned by the same over enterprise and would be different for separately owned MP and DSL.

Research suggests that the relative scale of the DSL to the MP (Richards, 2006), the degree of feed deficiency on the MP (Dalley et al., 2008), and the capabilities of management and the land being farmed (Bennett, 2009), are the key determinants of the range and extent of enterprises that the DSL supports. However, the drivers of the range and extent of enterprises were relatively inconclusive in this research, given the lack of information obtained on the MPs feed deficiency, the similarity of enterprises between farms, and the similar ratio of DSL to MP area (0.3-0.4: 1) between three of the farms (Farm A, B and D). However, it is likely that land use and management capability influenced the enterprises on the DSL to a small extent. For example, wintering activities were constrained by the soil on Farm B, suggesting the capabilities of land being farmed contributes to the enterprises that DSL supports. While Farm C could to winter the largest proportion (15%) of cows on his DSL block due to its intensive cropping rotation, this was supported by the business's joint contracting firm, implying management capabilities drove the intensity of the cropping enterprise.

6.3.1 Summary

The case study farms had three main management practices; replacement heifer grazing, cow wintering and producing supplementary feed for the MP. Contrary to the literature, there was a lack of diversity in management practices undertaken on these DSL. Further, replacement heifer grazing, as opposed to cow wintering, was the most significant management practice undertaken across the farms. There was inconclusive research regarding the key determinants of the range and extent of enterprises that DSL supports.

6.4 How do different DSL management practices currently impact the environmental performance of owned DSL in Selwyn Waihora?

Nitrogen leaching per hectare varied considerably between the four case study farms, ranging from 18.4 to 53.3 kgN/ha/year (average 37.2 kgN/ha/year). This section explores the different management systems that are likely to have contributed to this range of nitrogen leaching.

Research has shown that grazing winter forage crops contribute a disproportionally large proportion of the total nitrogen leached from the total dairy operation (Chrystal et al., 2012; Dalley, 2011; Monaghan et al., 2007; Monaghan, 2012). Consistent with these findings, this study found that on average, although winter grazing represented only 23% of the total DSL area, it was responsible for 57% of the farms total nitrogen losses (figure 9). On average, winter forage crops leached around 134 kgN/ha/year, which over 10 times the level leached from the pasture blocks (12 kgN/ha/year). This implies winter forage cropping practices adversely impact the environmental performance of owned DSL in Selwyn Waihora.

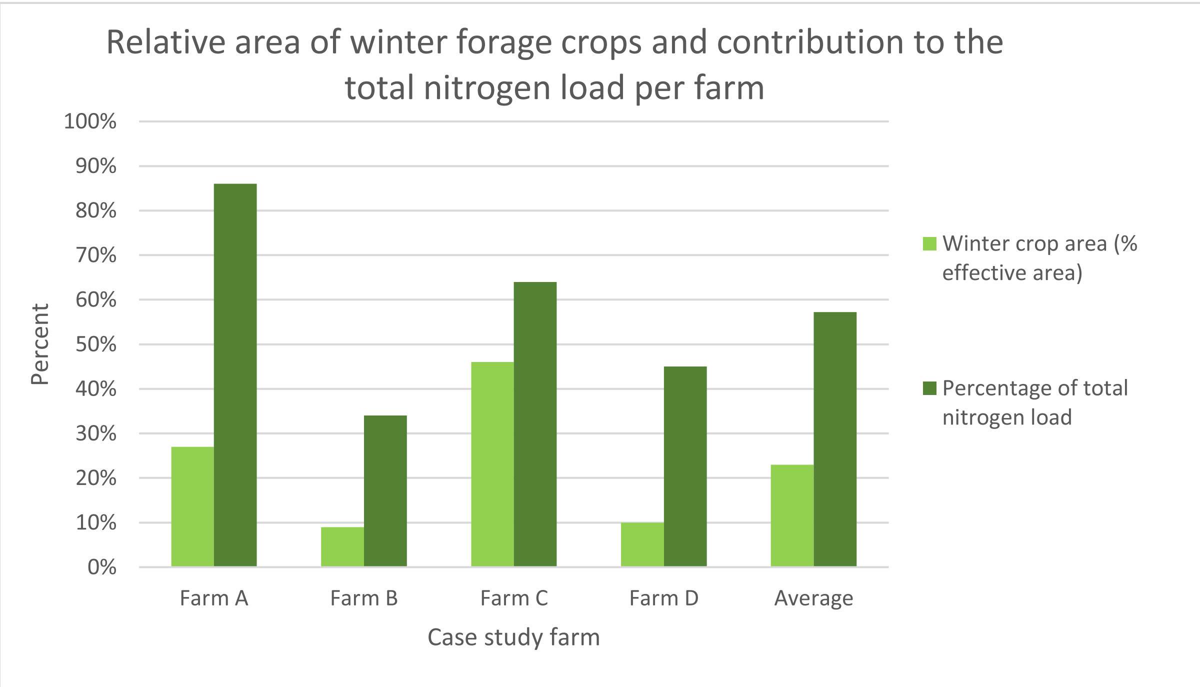

Figure 12: Relative area of winter forage crops and contributiom to the total nitrogen load per farm.

The literature also suggests that forage crop selection impacts nitrogen leaching levels, as feeds with lower CP concentrations reduce dietary and urine nitrogen concentrations environmental performance of DSL. In particular, soil drainage had a significant influence on nitrogen leaching. Poorly drained soils with high PAW dominated Farm B, which leached less than half of the nitrogen of the other farms. Further, a number of studies have shown large increases of leaching is strongly correlated with decreasing PAW (Brown & Zyskowski 2009; Cameron et al., 2002; Green & Clothier, 2009). While some farm management practices, particularly the area of winter forage cropping, impact on nitrogen leaching on DSL, a much more significant proportion of the nitrogen leaching is determined by biophysical factors (such as soil drainage characteristics) which are beyond the control of farmers.

6.4.1 Summary

A number of interconnected factors determine nitrogen leaching, and it is difficult to determine the extent to which these factors contribute to the variation in nitrogen leaching. Overall, biophysical factors, as opposed to management factors, are likely to contribute to a significant proportion of nitrogen leached from DSL. The proportion of winter forage crop occupying the total DSL area is likely to be the strongest management factor driving nitrogen leaching on DSL. However, this study found inconclusive evidence between farms on whether kale or fodder beet leached more nitrogen (according to Overseer). The use of forage barley as a cover crop improved the environmental performance of the farm.

6.5 How will Variation 1 impact the future physical, environmental and economic performance of DSL?

Environmentally, Variation 1 requires a 22% reduction in nitrogen leaching, this requirement significantly impacted on the physical and economic performance of DSL. The three main farm management practices used across the case study farms were grazing replacement heifers, wintering cows and producing supplementary feed for the MP. Therefore, the relative change in the number of stock on the DSL and supplementary feed exports to the MP were considered key indicators of the physical performance of DSL. Stock numbers were reduced by 5.4% on average across all the farms following the nitrogen mitigation strategies implemented on farm to meet Variation 1. However, there was significant variance (1.9% to 13.3%) between the farms. Farm D was the only farm to experience a change in the amount of supplementary feed exported, as 197 tDM of oats silage was made and sold to an external party. Therefore, in terms of physical performance, Variation 1 is likely to have the percentage change on these farms does not necessarily equate to the same reduction. For example, relative to Farms B and D, Farm C experienced a larger percentage reduction in operating profit yet had over twice as much operating profit.

It is important to consider that the absolute level of operating profit after meeting the Variation 1 requirements must be enough for a DSL farmer to meet other payment obligations including interest, tax, debt repayment and any reinvestment required in the farm. The financial analysis used for the standardised nitrogen mitigation protocol in this study excluded these payments to allow comparisons between farms. However, farms that may appear financially viable after meeting Variation 1 requirements may no longer be viable when these other payments are accounted for. This was shown when the interest cost associated with the stand-off pad structure was added to the operating expenses, as operating profit was reduced to almost zero for Farms B, C and D, while Farm A became financially unviable. This study recommends that an investment analysis is undertaken when considering capital intensive mitigations such as a standoff pad. In addition farms should consider their full business obligations when choosing how to meet Variation 1 requirements instead of looking just at operating profit.

6.5.1 Summary

Variation 1 is likely to have a significant influence on the number of stock the DSL can support, suggesting DSL may not meet the purposes it was purchased for in the future; to achieve control of livestock condition and eliminate volatility in grazing and feed costs. Overall, average operating profit is estimated to reduce by 11%, following implementation of the nitrogen mitigation protocol. The stand-off pad mitigation performed significantly worse environmentally and economically, however this mitigation allowed physical performance to remain relatively constant, particularly in stock carried. This research made some assumptions in relation to the cost of key inputs. In addition, focus is placed on relative change in operating profit following nitrogen mitigation, rather than a full financial analysis and absolute changes. It is important to read the results in relation to these assumptions and limitations.

6.6 How can dairy farmers with DSL in Selwyn Waihora achieve the nitrogen limits of Variation 1 in the most cost-effective manner?

Farmers need to understand how to meet their nitrogen constraints in the most cost effective manner, while this research has shown that they may chose an alternative mitigation strategy based on their primary purpose for having DSL, understanding the most cost effective way will allow them to make an informed choice in response to Variation 1. This is related to Howarth and Journeaux (2016) and Ledgard et al. (2006) who found nitrogen mitigations have differing effectiveness based on the farm they are applied on. For example, mitigation effectiveness differed between crop types on the same farm and the same crops on different farms. On Farm A, kale leached more than fodder beet, while both Farms C and D had higher nitrogen levels leached from fodder beet crops than on kale. This study also found that the establishment of a cover crop on Farm B increased nitrogen leaching, while the same cover crop reduced leaching on Farm D. Further, the replacement of high CP imported supplements which had a lower CP content had no impact on nitrogen leaching on Farm D. These findings highlight the importance of the farmer assessing the effectiveness of nitrogen mitigations before making significant and unnecessary farm system changes. Certified farm nutrient management advisors can provide this service and are likely to be highly valuable to farmers, as they meet their obligations under Variation 1. Improved simulations by future versions of Overseer are also likely to provide better understanding of the mitigation interactions.

Some mitigations were not applicable on the case study farms. For instance, Farm D had an intensive cropping rotation, therefore there was no scope to reduce pastoral nitrogen or establish cover crops. Likewise, Farm A and C only imported straw (a low CP feed), while Farm B did not import any supplements, therefore the diet manipulation of imported supplements was not applicable to these farms. Overall, the number of mitigations available to the farmer impacts their ability to be able to select the most appropriate way to reduce nitrogen for their business.

The cost-effectiveness of the mitigations used in the nitrogen mitigation protocol were analysed. This was determined by dividing the annualised net cost of each option by the quantity of nitrogen conserved (over the total farm area). On average, it cost $12 to remain more intensive. This is particularly true for those farmers who want to attain optimal control of their total dairying operation, and therefore eliminate the volatility associated with relying on external parties for support. This is important as it shows that farmers will not all chose to meet their Variation 1 requirements in the same way. This will be based on farmer perceptions and preference which is largely tied to their decisions to purchase the DSL.

Despite acknowledging that farmers may not all chose the most cost effective mitigation option, it is important to understand what this is in order to help inform farmers deciding how to respond to Variation 1. Therefore, this study has explored the impact if farmers use the most cost effective option. However, the mitigations implemented for each farm did account mitigations identified by the farmer as potentially favoured mitigation strategies. In particular, Farmer D emphasised the importance of reducing the fallow period over winter and utilising nitrogen with oat cover crops, which was consistent with the mitigation employed on his farm. Overall, this suggests that the farmers are already aware of the most cost effective mitigation available according to the constraints of their farm system.

Some of the farmers mentioned mitigations that they have adopted in order to reduce nitrogen (among other things), despite their lack of recognition by Overseer modelling. For instance, Farmer A and C have established diverse pastures, however this mitigation is currently not recognised by Overseer. This highlights that farmers are well informed of the suite of mitigation options to reduce nitrogen leaching, and emphasises the need for Overseer to continue to incorporate empirical research into the model to ensure that the farmers can benefit from these relatively new mitigations. Farmer B and C expressed their preference towards DCD if it came back on the market, suggesting that there is hope for the 'silver bullet' among farmers.

6.6.1 Summary

The cost-effectiveness of nitrogen mitigation largely depends on the context of individual farm systems; there is no 'one size fits all'. Therefore, farm advisors are likely to be highly valuable to farmers in assessing the cost-effectiveness of nitrogen mitigations (according to Overseer). The nitrogen mitigation protocol was significantly more cost-effective than the stand-off pad ($12/kgN and $175/kgN respectively). The establishment of an oats cover crop

Chapter 7

Conclusions

The objective of this research was to examine the implications of nitrogen regulation on the performance of DSL in the Selwyn Waihora catchment, and in doing so, address a gap in the literature. The intention was to assist farmers in making informed decisions when considering how to meet their obligations under Variation 1, and to help inform policy creation in other areas and direction for future research.

Four dairy farmers that owned DSL in the Selwyn Waihora catchment were interviewed to obtain physical, financial and environmental data, as well as qualitative information pertaining to DSL ownership. Farm system modelling was used to identify the abatement cost of reducing nitrogen leaching under Variation 1, this used Oversee and Farmax. The lowest cost mitigation strategies were used, in addition to a stand-off pad structure.

This research found that Variation 1 is likely to have significant impacts on the future physical performance of DSL in Selwyn Waihora. Winter forage cropping was an integral component of all the DSL farms. However, the proportion of winter forage crop occupying the total DSL area was the strongest management factor increasing nitrogen leaching on DSL. Consequently, the mitigations were largely focused on reducing the losses of these crops. Stock numbers were reduced by 5.4% on average across all farms following nitrogen mitigation. This suggests that there will be a decrease in the availability of DSL in the Selwyn Waihora catchment as DSL reduces the stock they carry over winter to reduce their nitrogen leaching. This would also impact on the ability of DSL to meet a common primary objective of purchase; to attain direct control the condition of livestock and therefore, enhance the performance of the overall dairy system. This will have many flow-on effects in the wider agriculture industry, requiring additional support from third party graziers.

Mitigating nitrogen leaching from DSL was shown to reduce operating profit; this report estimates that a 22% reduction in nitrogen leaching will reduce operating profit by 11%, on average. The stand-off pad structure was only able to reduce nitrogen leaching by 15%, reducing operating profit by 53.1%. Overall, the iterative nitrogen mitigations used were

Chapter 8

Limitations

One limitation of this research is that it does not reduce nitrogen leaching losses from the baseline (2009 to 2013) average, as required by Variation 1. Rather the baseline was set as the current 2015-16 season, as two of the farmers had purchased their DSL properties after 2011 and did not have access to the previous farmers fertiliser, stock and feed records to create the Overseer baseline model. Although this is not the ideal situation given the policy context, it was a necessary starting point for this research given on data available. This approach allowed consistency between farms and was considered more accurate than basing the baseline on anecdotal assumptions of the farming system operated by the previous owner. This study does not attempt to predict what the regional council may do in situations similar to these.

The research approach uses case study farms. While this provides real data for each farm and covers a wide range of biophysical and farm system characteristics, the degree of which the farms are representative is uncertain. This is particularly the case given the absence of robust, accessible data on the range of DSL systems in Selwyn Waihora or the wider Canterbury region. In comparison to the production averages in the Selwyn District in 2014-15, all the MPs owned by the case study farmers had a higher stocking rate per hectare and greater milk production per cow. The average herd size and farm size was also above the district average, and all the farmers owned more than one dairy farm. Further, all the case study farmers were considered good farmers with a good grasp on farm management, animal nutrition and financial management. In this respect the sample shows a degree of bias towards larger, higher producing farms and above average farmers. However, this study does not attempt to seek definitive answers that reflect the position of all Selwyn Waihora DSL farmers. Rather it is hoped that the results from this research can be utilised by farmers to support decisions in selecting and implementing mitigation strategies to their own farm system.

This research is limited by the assumptions and constraints of Overseer. The key assumptions underpinning the model are described in section 3.4.1. The Overseer